(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: **0 598 917 A1**

(12) # EUROPEAN PATENT APPLICATION published in accordance with Art. 158(3) EPC

(21) Application number: **93913502.6**

(22) Date of filing: **10.06.93**

(86) International application number: **PCT/JP93/00778**

(87) International publication number: **WO 93/25806 (23.12.93 93/30)**

(51) Int. Cl.5: **F01N 3/28**, F01N 3/24, B01D 53/34, B01J 23/58, F02D 41/02

(30) Priority: **12.06.92 JP 177666/92**
25.06.92 JP 190213/92
29.12.92 JP 361575/92

(43) Date of publication of application: **01.06.94 Bulletin 94/22**

(84) Designated Contracting States: **DE FR GB**

(71) Applicant: **TOYOTA JIDOSHA KABUSHIKI KAISHA**
1, Toyota-cho
Toyota-shi
Aichi-ken 471(JP)

(72) Inventor: **TAKESHIMA, Shinichi, c/o Toyota Jidosha K.K.**
1, Toyota-cho
Toyota-shi, Aichi(JP)
Inventor: **TANAKA, Toshiaki, c/o Toyota Jidosha K.K.**
1, Toyota-cho
Toyota-shi, Aichi(JP)
Inventor: **IGUCHI, Satoshi, c/o Toyota Jidosha K.K.**
1, Toyota-cho
Toyota-shi, Aichi(JP)
Inventor: **ARAKI, Yasushi, Toyota Jidosha K.K.**
1, Toyota-cho
Toyota-shi, Aichi(JP)
Inventor: **HIROTA, Shinya, Toyota Jidosha K.K.**
1, Toyota-cho
Toyota-shi, Aichi(JP)
Inventor: **ODA, Tomohiro, Toyota Jidosha K.K.**
1, Toyota-cho
Toyota-shi, Aichi(JP)
Inventor: **MURAKAMI, Fumitada, Toyota Jidosha K.K.**
1, Toyota-cho
Toyota-shi, Aichi(JP)

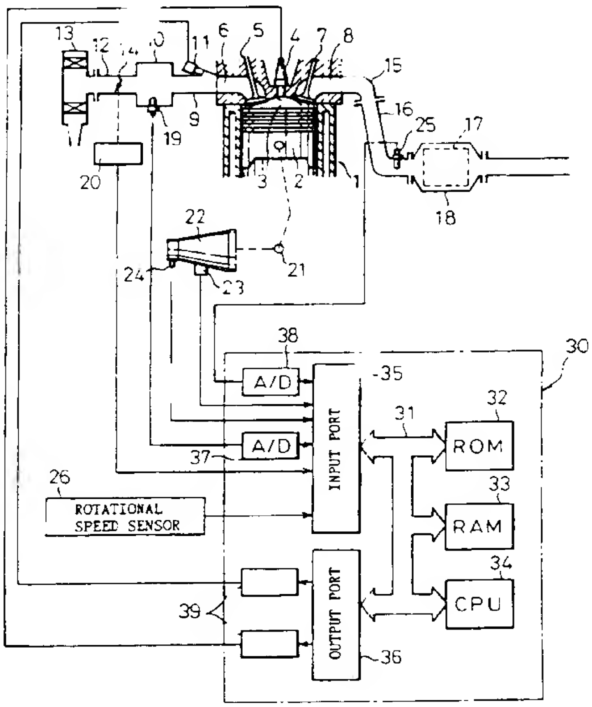
(74) Representative: **Tiedtke, Harro, Dipl.-Ing. et al**
Patentanwaltsbüro
Tiedtke-Bühling-Kinne & Partner
Bavariaring 4
D-80336 München (DE)

(54) **EXHAUST EMISSION CONTROL SYSTEM FOR INTERNAL COMBUSTION ENGINE.**

(57) An NOx absorbing agent (17) is disposed inside an exhaust gas passage of a combustion engine. This NOx absorbing agent (17) absorbs NOx when the air/fuel ratio of exhaust gas flowing thereinto is lean, and discharges NOx which it has absorbed when the air/fuel ratio of exhaust gas flowing thereinto becomes rich. The amount of NOx absorbed in the NOx absorbing agent (17) is estimated from the engine load and the number of revolutions of the engine, and when this estimated NOx amount becomes the maximum NOx absorbing capacity of the NOx absorbing agent (17), the air/fuel ratio of exhaust gas flowing into the NOx absorbing agent (17) is made rich.

EP 0 598 917 A1

Fig.1


ROTATIONAL SPEED SENSOR
A/D
A/D
INPUT PORT
OUTPUT PORT
ROM
RAM
CPU

TECHNICAL FIELD

The present invention relates to an exhaust purification device of an internal combustion engine.

BACKGROUND ART

A diesel engine in which an engine exhaust passage is branched to a pair of exhaust branch passages for purifying NO_x in the diesel engine, a switching valve is disposed at the branched portion of these exhaust branch passages, the switching valve is switched each time a predetermined time passes to alternately guide the exhaust gas to one of the exhaust branch passages, and a catalyst which can oxidize and absorb the NO_x is disposed in each of the exhaust branch passages is well known (refer to Japanese Unexamined Patent Publication No. 62-106826). In this diesel engine, the NO_x in the exhaust gas introduced into one exhaust branch passage is oxidized and absorbed by the catalyst disposed in that exhaust branch passage. During this time, the inflow of the exhaust gas to the other exhaust branch passage is stopped and, at the same time, a gaseous reducing agent is fed into this exhaust branch passage. The NO_x accumulated in the catalyst disposed in this exhaust branch passage is reduced by this reducing agent. Subsequently, after the elapse of a predetermined time, the introduction of the exhaust gas to the exhaust branch passage to which the exhaust gas had been introduced heretofore is stopped by the switching function of the switching valve, and the introduction of the exhaust gas to the exhaust branch passage to which the introduction of the exhaust gas had been stopped heretofore is started again. That is, in this diesel engine, seen from the viewpoint of each of the exhaust branch passages, exhaust gas is made to flow for a predetermined time during which the NO_x in the exhaust gas is oxidized and absorbed by the catalyst, then the inflow of exhaust gas is stopped for a predetermined period and a reducing agent is fed, whereby the NO_x accumulated in the catalyst is reduced.

However, the amount of the NO_x which is discharged from the engine changes depending on the operating condition of the engine and therefore the amount of the NOx which is oxidized and absorbed by the catalyst during the predetermined time when the exhaust gas is flowing changes depending on the operating state of the engine during that period. Accordingly, there is the problem that when an engine operating condition under which a large amount of NO_x is discharged continues, the NO_x oxidizing and absorbing ability of the catalyst ends up becoming saturated during the predetermined time in which the exhaust gas flows and as a result the NO_x can no longer be oxidized and absorbed by the NO_x absorbent, so the NO_x is released into the atmosphere.

As opposed to this, when an engine operating condition in which a small amount of NO_x is discharged continues, only a small amount of NO_x is oxidized and absorbed in the predetermined time in which the exhaust gas flows. Accordingly, in this case, when the inflow of the exhaust gas is stopped and the reducing agent is fed, only part of the reducing agent is used for the reduction of the NO_x and the reducing agent becomes in excess, resulting in the problem of the release of this excess reducing agent into the atmosphere.

DISCLOSURE OF THE INVENTION

An object of the present invention is to provide an exhaust purification device which can reduce well the harmful components released into the atmosphere regardless of the magnitude of the amount of the NO_x discharged from the engine.

According to the present invention, there is provided an exhaust purification device of an internal combustion engine which has in an engine exhaust passage a NO_x absorbent which absorbs the NO_x when the air-fuel ratio of the inflowing exhaust gas is lean and which releases the absorbed NO_x when the oxygen concentration in the inflowing exhaust gas is reduced and which is provided with a NO_x estimating means for estimating the amount of the NO_x absorbed by the NO_x absorbent and a NO_x releasing means for reducing the oxygen concentration in the exhaust gas flowing into the NO_x absorbent and releasing NO_x from the NO_x absorbent when the amount of the NO_x estimated to be absorbed in the NO_x absorbent by the NO_x estimating means exceeds a predetermined allowable value.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an overall view of an internal combustion engine; Fig. 2 is a diagram showing a map of a basic fuel injection time; Fig. 3 is a diagram showing a correction coefficient K; Fig. 4 is a graph schematically showing the concentration of unburnt HC, CO, and oxygen in the exhaust gas discharged from the engine; Fig. 5 is a diagram for explaining an absorption and release function of the NO_x; Fig. 6 is a diagram showing the amount of NO_x discharged from the engine, Fig. 7 is a graph showing the capacity of absorption of NO_x of the NO_x absorbent; Fig. 8 is a graph showing the characteristics of release of NO_x; Fig. 9 is a graph showing the change in the correction coefficient K; Fig. 10 is a graph showing C_1, C_2, α, and β; Fig. 11 is a diagram showing a map of the exhaust gas tem-

perature T; Fig. 12 and Fig. 13 are flow charts showing a time interruption routine; Fig. 14 is a flow chart for calculating the fuel injection time TAU; Fig. 15 and Fig. 16 are flow charts showing a time interruption routine of another embodiment; Fig. 17 to Fig. 19 are a flow chart for calculating the fuel injection time TAU of another embodiment; Fig. 20 is a graph showing the correction coefficient K_t; Fig. 21 is an overall view of an internal combustion engine showing another embodiment; Fig. 22 is an overall view of an internal combustion engine showing still another embodiment; Fig. 23 is a graph showing the amount of NO_x discharged from the engine; Fig. 24 is a graph showing the NO_x absorption characteristic of a NO_x absorbent; Fig. 25 is a graph showing the residual rate of the NO_x remaining in the NO_x absorbent; Fig. 27 is an overall view of a diesel engine showing still another embodiment; and Fig. 28 to Fig. 30 are a flow chart showing the control of NO_x release.

BEST MODE FOR CARRYING OUT THE INVENTION

Figure 1 shows a case where the present invention is applied to a gasoline engine.

Referring to Fig. 1, 1 denotes an engine body; 2, a piston; 3, a combustion chamber; 4, a spark plug; 5, an intake valve; 6, an intake port; 7, an exhaust valve; and 8, an exhaust port, respectively. The intake port 6 is connected to a surge tank 10 via a corresponding branch pipe 9, and a fuel injector 11 injecting the fuel toward the interior of the intake port 6 is attached to each branch pipe 9. The surge tank 10 is connected to an air cleaner 13 via an intake duct 12, and a throttle valve 14 is disposed in the intake duct 12. On the other hand, the exhaust port 8 is connected via an exhaust manifold 15 and an exhaust pipe 16 to a casing 18 including a NO_x absorbent 17.

An electronic control unit 30 comprises a digital computer and is provided with a ROM (read only memory) 32, a RAM (random access memory) 33, a CPU (microprocessor) 34, an input port 35, and an output port 36, which are interconnected by a bidirectional bus 31. In the surge tank 10 is mounted a pressure sensor 19 for generating an output voltage proportional to the absolute pressure in the surge tank 10. The output voltage of this pressure sensor 19 is input through an AD converter 37 to the input port 35. Further, the throttle valve 14 has attached to it an idle switch 20 which detects when the throttle valve 14 is open to the idling state. The output signal of this idle switch 20 is input to the input port 35.

On the other hand, a crankshaft 21 has connected to it, for example, an automatic transmission 22. This automatic transmission 22 has attached to it a gear position detector 23 for detecting the position of the transmission gears and a vehicle speed sensor 24 for detecting the speed of the vehicle. The output signals of the gear position detector 23 and the vehicle speed sensor 24 are input to the input port 35. Further, in the exhaust pipe 16 upstream of the casing 18 there is attached a temperature sensor 25 for generating an output voltage proportional to the temperature of the exhaust gas. The output voltage of the temperature sensor 25 is input through an AD converter 38 to the input port 35. Further, the input port 35 has connected to it a rotational speed sensor 26 for generating an output pulse expressing the engine rotational speed. On the other hand, the output port 36 is connected through a corresponding drive circuit 39 to the respective spark plug 4 and fuel injector 11.

In the internal combustion engine shown in Fig. 1, the fuel injection time TAU is calculated based on for example the following equation.

$$TAU = TP \cdot K$$

where, TP is a basic fuel injection time, and K is a correction coefficient. The basic fuel injection time TP shows the fuel injection time necessary for bringing the air-fuel ratio of an air-fuel mixture fed into the engine cylinder to the stoichiometric air-fuel ratio. This basic fuel injection time TP is found in advance by experiments and is stored in advance in the ROM 32 in the form of a map as shown in Fig. 2 as the function of the absolute pressure PM in the surge tank 10 and the engine rotational speed N. The correction coefficient K is a coefficient for controlling the air-fuel ratio of the air-fuel mixture fed into the engine cylinder, and if K = 1.0, the air-fuel mixture fed into the engine cylinder becomes the stoichiometric air-fuel ratio. Contrary to this, when K becomes smaller than 1.0, the air-fuel ratio of the air-fuel mixture fed into the engine cylinder becomes larger than the stoichiometric air-fuel ratio, that is, becomes lean, and when K becomes larger than 1.0, the air-fuel ratio of the air-fuel mixture fed into the engine cylinder becomes smaller than the stoichiometric air-fuel ratio, that is, becomes rich.

The value of this correction coefficient K is predetermined in relation to the absolute pressure PM in the surge tank 10 and the engine rotational speed N. Figure 3 shows an embodiment of the value of the correction coefficient K. In the embodiment shown in Fig. 3, in the region where the absolute pressure PM in the surge tank 10 is relatively low, that is, in the engine low and medium load operation region, the value of the correction coefficient K is made a value smaller than 1.0, therefore at this time the air-fuel ratio of the air-fuel

mixture fed into the engine cylinder is made lean. On the other hand, in the region where the absolute pressure PM in the surge tank 10 is relatively high, that is, in the engine high load operation region, the value of the correction coefficient is made 1.0. Accordingly, at this time, the air-fuel ratio of the air-fuel mixture fed into the engine cylinder is made the stoichiometric air-fuel ratio. Further, in the region where the absolute pressure PM in the surge tank 10 becomes the highest, that is, in the engine full load operation region, the value of the correction coefficient is made a value larger than 1.0. Therefore, at this time, the air-fuel ratio of the air-fuel mixture fed into the engine cylinder is made rich. An internal combustion engine is usually operated most frequently with a low and medium load and therefore for the majority of the period of]operation a lean air-fuel mixture is burned.

Figure 4 schematically shows the concentration of representative components in the exhaust gas discharged from the combustion chamber 3. As seen from Fig. 4, the concentration of the unburnt HC and CO in the exhaust gas discharged from the combustion chamber 3 is increased as the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 becomes richer, and the concentration of the oxygen O_2 in the exhaust gas discharged from the combustion chamber 3 is increased as the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 becomes leaner.

The NO_x absorbent 17 contained in the casing 18 uses, for example, alumina as a carrier. On this carrier, at least one substance selected from alkali metals, for example, potassium K, sodium Na, lithium Li, and cesium Cs; alkali earths, for example, barium Ba and calcium Ca; and rare earths, for example, lanthanum La and yttrium Y and a precious metal such as platinum Pt are carried. When referring to the ratio between the air and fuel (hydrocarbons) fed into the intake passage of the engine and the exhaust passage upstream of the NO_x absorbent 17 as the air-fuel ratio of the inflowing exhaust gas flowing into the NO_x absorbent 17, this NO_x absorbent 17 performs the absorption and releasing function of NO_x by absorbing the NO_x when the air-fuel ratio of the inflowing exhaust gas is lean, while releasing the absorbed NO_x when the concentration of oxygen in the inflowing exhaust gas falls. Note that, where the fuel (hydrocarbons) or air is not fed into the exhaust passage upstream of the NO_x absorbent 17, the air-fuel ratio of the inflowing exhaust gas coincides with the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3, and accordingly in this case, the NO_x absorbent 17 absorbs the NO_x when the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is lean and releases the absorbed NO_x when the concentration of oxygen in the air-fuel mixture fed into the combustion chamber 3 is lowered.

When the above-mentioned NO_x absorbent 17 is disposed in the exhaust passage of the engine, this NO_x absorbent 17 actually performs the absorption and releasing function of NO_x, but there are areas of the exact mechanism of this absorption and releasing function which are not clear. However, it can be considered that this absorption and releasing function is conducted by the mechanism as shown in Fig. 5. This mechanism will be explained by using as an example a case where platinum Pt and barium Ba are carried on the carrier, but a similar mechanism is obtained even if another precious metal, alkali metal, alkali earth, or rare earth is used.

Namely, when the inflowing exhaust gas becomes considerably lean, the concentration of oxygen in the inflowing exhaust gas is greatly increased. As shown in Fig. 5(A), the oxygen O_2 is deposited on the surface of the platinum Pt in the form of O_2^- or O^{2-}. On the other hand, the NO in the inflowing exhaust gas reacts with the O_2^- or O^{2-} on the surface of the platinum Pt and becomes NO_2 ($2NO + O_2 \rightarrow 2NO_2$). Subsequently, a part of the produced NO_2 is oxidized on the platinum Pt and absorbed into the absorbent. While bonding with the barium oxide BaO, it is diffused in the absorbent in the form of nitric acid ions NO_3^- as shown in Fig. 5(A). In this way, NO_x is absorbed into the NO_x absorbent 17.

So long as the oxygen concentration in the inflowing exhaust gas is high, the NO_2 is produced on the surface of the platinum Pt, and so long as the NO_x absorption ability of the absorbent is not saturated, the NO_2 is absorbed into the absorbent and nitric acid ions NO_3^- are produced. Contrary to this, when the oxygen concentration in the Inflowing exhaust gas is lowered and the production of NO_2 is lowered, the reaction proceeds in an inverse direction ($NO_3^- \rightarrow NO_2$), and thus nitric acid ions NO_3^- in the absorbent are released in the form of NO_2 from the absorbent. Namely, when the oxygen concentration in the inflowing exhaust gas is lowered, the NO_x is released from the NO_x absorbent 17. As shown in Fig. 4, when the degree of leanness of the inflowing exhaust gas becomes low, the oxygen concentration in the inflowing exhaust gas is lowered. and accordingly when the degree of leanness of the inflowing exhaust gas is lowered, the NO_x is released from the NO_x absorbent 17 even if the air-fuel ratio of the inflowing exhaust gas is lean.

On the other hand, at this time, when the air-fuel ratio of the air-fuel mixture fed into the combustion chamber 3 is made rich and the air-fuel ratio of the inflowing exhaust gas becomes rich, as shown in Fig. 4, a large amount of unburnt HC and

CO is discharged from the engine, and these unburnt HC and CO react with the oxygen O_2^- or O^{2-} on the platinum Pt and are oxidized. Also, when the air-fuel ratio of the inflowing exhaust gas becomes rich, the oxygen concentration in the inflowing exhaust gas is extremely lowered, and therefore the NO_2 is discharged from the absorbent. This NO_2 reacts with the unburnt HC and CO as shown in Fig. 5(B) and is reduced. In this way, when the NO_2 no longer exists on the surface of the platinum Pt, the NO_2 is successively released from the absorbent. Accordingly, when the air-fuel ratio of the inflowing exhaust gas is made rich, the NO_x is released from the NO_x absorbent 19 in a short time.

Namely, when the air-fuel ratio of the inflowing exhaust gas is made rich, first of all, the unburnt HC and CO immediately react with the O_2^- or O^{2-} on the platinum Pt and are oxidized, and subsequently if the unburnt HC and CO still remain even though the O_2^- or O^{2-} on the platinum Pt is consumed, the NO_x released from the absorbent and the NO_x discharged from the engine are reduced by these unburnt HC and CO. Accordingly, when the air-fuel ratio of the inflowing exhaust gas is made rich, the NO_x absorbed in the NO_x absorbent 17 is released in a short time and in addition this released NO_x is reduced, and therefore the discharge of NO_x into the atmosphere can be blocked. Also, since the NO_x absorbent 17 has the function of a reduction catalyst, even if the air-fuel ratio of the inflowing exhaust gas is made the stoichiometric air-fuel ratio, the NO_x released from the NO_x absorbent 17 can be reduced. However, where the air-fuel ratio of the inflowing exhaust gas is made the stoichiometric air-fuel ratio, the NO_x is released merely gradually from the NO_x absorbent 17, and therefore a slightly long time is required for releasing all NO_x absorbed in the NO_x absorbent 17.

When the degree of leanness of the inflowing exhaust gas is lowered as mentioned before, even if the air-fuel ratio of the inflowing exhaust gas is lean, the NO_x is released from the NO_x absorbent 17. Accordingly, so as to release the NO_x from the NO_x absorbent 17, it is satisfactory if the concentration of oxygen in the inflowing exhaust gas is lowered. Note, even if the NO_x is released from the NO_x absorbent 17, when the air-fuel ratio of the inflowing exhaust gas is lean, the NO_x is not reduced in the NO_x absorbent 17, and accordingly, in this case, it is necessary to provide a catalyst which can reduce the NO_x downstream of the NO_x absorbent 17 or supply a reducing agent downstream of the NO_x absorbent 17. Of course, it is also possible to reduce the NO_x downstream of the NO_x absorbent 17 in this way, but it is rather preferable that the NO_x be reduced in the NO_x absorbent 17. Accordingly, in the embodiment according to the present invention, when the NO_x should be released from the NO_x absorbent 17, the air-fuel ratio of the inflowing exhaust gas is made rich, whereby the NO_x released from the NO_x absorbent 17 is reduced in the NO_x absorbent 17.

However, in the embodiment according to the present invention, as mentioned above, during full load operation, the air-fuel mixture fed into the engine cylinder 3 is made rich and during high load operation, the air-fuel mixture is made the stoichiometric air-fuel ratio, so during the full load operation and the high load operation, the NO_x is released from the NO_x absorbent 17. However, if the frequency of this full load operation or high load operation is small, then even if the NO_x is released from the NO_x absorbent 17 only during full load operation and high load operation, the absorption capacity of the NO_x by the NO_x absorbent 17 will end up becoming saturated during the time when a lean air-fuel mixture is burnt and therefore it will end up becoming impossible for the NO_x absorbent 17 to absorb the NO_x. Accordingly, in the embodiment according to the present invention, when a lean air-fuel mixture continues to be burnt, the air-fuel mixture fed into the combustion chamber 3 is cyclically made rich and during this time the NO_x is released from the NO_x absorbent 17.

In this case, however, if the cycle at which the air-fuel mixture fed into the engine cylinder 3 is made rich is long, then the NO_x absorbing capacity of the NO_x absorbent 17 will end up becoming saturated during the time the lean air-fuel mixture is being burnt and therefore the NO_x can no longer be absorbed in the NO_x absorbent 17, so there will be the problem that NO_x will end up being released into the atmosphere. As opposed to this, even if an engine operating state where a large amount of NO_x is discharged from the engine continues, if the cycle at which the air-fuel mixture is made lean is shortened so that the NO_x is released from the NO_x absorbent 17 before the NO_x absorbing capacity of the NO_x absorbent 17 becomes saturated, then this time the problem will arise of an increase of the amount of fuel consumption.

Therefore, in the present invention, the amount of NO_x which is absorbed in the NO_x absorbent 17 is found and the air-fuel mixture is made rich when the amount of the NO_x absorbed in the NO_x absorbent 17 exceeds a predetermined allowable value. If the air-fuel mixture is made rich when the amount of the NO_x absorbed in the NO_x absorbent 17 exceeds a predetermined allowable value, then the NO_x absorbing capacity of the NO_x absorbent 17 will never become saturated, so the NO_x will no longer be released into the atmosphere and, further, the frequency at which the air-fuel mixture is

made rich can be reduced as well, so it is possible to suppress an increase in the amount of the fuel consumption.

However, when finding the amount of NO_x being absorbed in the NO_x absorbent 17, it is difficult to directly find the amount of NO_x being absorbed in the NO_x absorbent 17. Therefore, in the present invention, the amount of the NO_x absorbed in the NO_x absorbent 17 is estimated from the amount of NO_x in the exhaust gas discharged from the engine. That is, the higher the rotational speed N of the engine, the larger the amount of exhaust gas discharged per unit time from the engine, so as the engine rotational speed N becomes higher, the amount of NO_x discharged from the engine per unit time increases. Further, the higher the engine load, that is, the higher the absolute pressure PM in the surge tank 10, the greater the amount of the exhaust gas discharged from the combustion chambers 3 and further the higher the combustion temperature, so the higher the engine load, that is, the higher the absolute pressure PM in the surge tank 10, the greater the amount of NO_x discharged from the engine per unit time.

Figure 6(A) shows the relationship between the amount of the NO_x discharged from the engine per unit time, the absolute pressure PM in the surge tank 10, and the engine rotational speed N as found by experiments. In Fig. 6(A), the curves show the identical amounts of NO_x. As shown in Fig. 6(A), the amount of NO_x discharged from the engine per unit time becomes larger the higher the absolute pressure PM in the surge tank 10 and becomes larger the higher the engine rotational speed N. Note that the amount of NO_x shown in Fig. 6(A) is stored in the ROM 32 in advance in the form of a map as shown in Fig. 6(B).

On the other hand, Fig. 7 shows the relationship between the absorption capacity NO_xCAP which can be absorbed by the NO_x absorbent 17 and the temperature T of the exhaust gas, which represents the temperature of the NO_x absorbent 17. If the temperature of the NO_x absorbent 17 becomes lower, that is, the temperature T of the exhaust gas becomes lower, the oxidation action of the NO_x ($2NO + O_2 \rightarrow 2NO_2$) is weakened, and therefore the NO_x absorption capacity NO_xCAP is lowered. Further, if the temperature of the NO_x absorbent 17 becomes higher, that is, the temperature T of the exhaust gas becomes higher, the NO_x absorbed in the NO_x absorbent 17 is decomposed and naturally released, so the NO_x absorption capacity NO_xCAP is lowered. Accordingly, the NO_x absorption capacity NO_xCAP becomes larger between about 300 °C to about 500 °C.

On the other hand, Fig. 8 shows the results of experiments on the amount of NO_x released from the NO_x absorbent 17 when switching the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent 17 from lean to rich. Note that the solid line in Fig. 8 shows the state when the temperature of the NO_x absorbent 17, that is, the temperature T of the exhaust gas, is high, while the broken line shows when the temperature of the NO_x absorbent 17, that is, the temperature T of the exhaust gas, is low. The rate of decomposition of the NO_x in the NO_x absorbent 17 becomes faster the higher the temperature of the NO_x absorbent 17. Therefore, when the temperature of the NO_x absorbent 17 is high, as shown by the solid line in Fig. 8, that is, when the temperature T of the exhaust gas is high, a large amount of NO_x is released from the NO_x absorbent 17 in a short time, while when the temperature of the NO_x absorbent 17, that is, the temperature T of the exhaust gas, is low, as shown by the broken line in Fig. 8, a small amount of NO_x is continually released from the NO_x absorbent 17 over a long period. That is, the higher the temperature T of the exhaust gas, the greater the amount of NO_x released from the NO_x absorbent 17 per unit time and the shorter the release time of the NO_x.

When the amount of the unburnt HC and CO discharged from the engine, however, is smaller than the amount which can reduce the total NO_x released from the NO_x absorbent 17, part of the NO_x is released into the atmosphere without being reduced, while when the amount of unburnt HC and CO discharged from the engine is greater than the amount able to reduce the total NO_x released from the NO_x absorbent 17, the excess unburnt HC and CO are released into the atmosphere. Accordingly, to prevent the NO_x and the unburnt HC and CO from being released into the atmosphere, it is necessary to discharge exactly the amount of the unburnt HC and CO from the engine needed to reduce the NO_x released from the NO_x absorbent 17. Toward this end, it becomes necessary to increase the amount of the unburnt HC and CO in accordance with the curve shown in Fig. 8.

As mentioned earlier, however, the amount of the unburnt HC and CO discharged from the engine is proportional to the degree of richness of the air-fuel mixture fed into the combustion chamber 3. Therefore, in the embodiment according to the present invention, as shown in Fig. 9, the value of the correction coefficient k with respect to the basic fuel injection time TP, that is, the degree of richness of the air-fuel mixture, is made to change in accordance with a pattern as close as possible to the pattern of change of the concentration of NO_x shown in Fig. 8. Note that here, the correction coefficient k has the relationship $K = 1 + k$ with the above-mentioned correction coefficient K and therefore when $k = 0$, the air-fuel mixture becomes the stoichiometric air-fuel ratio while when $k > 0$,

the air-fuel mixture becomes rich.

As shown by the solid line in Fig. 9, when the NO_x is to be released from the NO_x absorbent 17, the correction coefficient k is made to rise by α increments with each passing of the unit time until the time C reaches C_1. Next, when the time C is between C_1 and C_2, the correction coefficient k is held constant, then when the time C exceeds C_2, the correction coefficient k is made to descend in β decrements with each unit time. The values of these α, β, C_1, and C_2 are set so that the pattern of change of the correction coefficient k becomes as close as possible to the pattern of change of the concentration of NO_x shown by the solid line in Fig. 8.

On the other hand, the pattern of change of the correction coefficient k when the temperature of the NO_x absorbent 17, that is, the temperature T of the exhaust gas, is low, is also set so that it becomes as close as possible to the pattern of change of the concentration of NO_x when the temperature T of the exhaust gas is low, as shown by the broken line in Fig. 8. In this case, to make the pattern of change of the correction coefficient k in Fig. 9 like the broken line, it is understood that it is sufficient to make both α and β smaller and make C_1 and C_2 larger. That is, to make the pattern of change of the correction coefficient k close to the pattern of change of the concentration of NO_x shown in Fig. 8, it is sufficient to make α and β larger and make C_1 and C_2 smaller as the temperature T of the exhaust gas becomes higher, as shown in Fig. 10. Note that the relationship between C_1, C_2, α, and β and the temperature T of the exhaust gas shown in Fig. 10 is stored in advance in the ROM 32.

Note that in the embodiment according to the present invention, provision is made of a temperature sensor 25 for detecting the temperature T of the exhaust gas and accordingly the NO_x absorption capacity NO_x CAP shown in Fig. 7 and the α, β, C_1, and C_2 shown in Fig. 10 are determined based on the temperature T of the exhaust gas detected by this temperature sensor 25. The temperature T of the exhaust gas, however, can be estimated from the absolute pressure PM in the surge tank 10 and the engine rotational speed N. Therefore, instead of providing the temperature sensor 25, it is possible to store the temperature T of the exhaust gas in the ROM 32 in advance in the form of a map as shown in Fig. 11 and determine the NO_x absorption capacity NO_x CAP and α, β, C_1, and C_2 based on the temperature T of the exhaust gas obtained from this map.

Next, an explanation will be made of the first embodiment of control of the release of NO_x with reference to Fig. 12 to Fig. 14.

Figure 12 and Fig. 13 show a time interruption routine executed by interruption every predetermined time.

Referring to Fig. 12 and Fig. 13, first, at step 100, it is judged if a NO_x release flag showing that the NO_x should be released from the NO_x absorbent 17 is set or not. When the NO_x release flag is not set, the routine proceeds to step 101, where it is judged if the correction coefficient K is smaller than 1.0, that is, if the operating state is one in which the air-fuel mixture should be made lean. When $K < 1.0$, that is, when the operating state is one in which the air-fuel mixture should be made lean, the routine proceeds to step 102, where the count D is made zero, then the routine proceeds to step 103.

At step 103, the NO_x amount Nij discharged from the engine per unit time is calculated from the map shown in Fig. 6(B) based on the absolute pressure PM in the surge tank 10, detected by the pressure sensor 19, and the engine rotational speed N. Next, at step 104, the NO_x amount Nij is multiplied by the interruption time interval Δt and the product $Nij \bullet \Delta T$ is added to ΣNO_x. The product $Nij \bullet \Delta t$ shows the amount of the NO_x discharged from the engine during the interruption time interval Δt. At this time, the NO_x discharged from the engine is absorbed by the NO_x absorbent 17, so ΣNO_x shows the estimated value of the amount of NO_x absorbed in the NO_x absorbent 17.

Next, at step 105, the NO_x absorption capacity NO_x CAP is calculated from the relationship shown in Fig. 7 based on the temperature T of the exhaust gas detected by the temperature sensor 25. Next, at step 106, it is judged if the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 has exceeded the NO_x absorption capacity $NO_x CAP$. When $\Sigma NO_x \leq NO_x CAP$, the processing cycle is completed. At this time, a lean air-fuel mixture is burned and the NO_x discharged from the engine is absorbed in the NO_x absorbent 17.

On the other hand, if it is judged at step 106 that $\Sigma NO_x > NO_x CAP$, that is, the NO_x absorption capacity of the NO_x absorbent 17 is saturated, the routine proceeds to step 107, where the NO_x release flag is set. Next, at step 108, C_1, C_2, α, and β are calculated from the relation shown in Fig. 10 based on the temperature T of the exhaust gas and the processing cycle is ended. If the NO_x release flag is set, at the next processing cycle, the routine proceeds from step 100 to step 109, where the count C is incremented by one. Next, at step 110, it is judged if the count C is smaller than C_1. When $C < C_1$, the routine proceeds to step 111, where α is added to the correction coefficient k. Next, the processing cycle is ended. The action of addition of α to the correction coefficient k is performed continuously until $C \geq C_1$. Accordingly, the value of the correction coefficient k during this time contin-

ues to increase as shown in Fig. 9.

On the other hand, if it is judged at step 110 that $C \geqq C_1$, the routine proceeds to step 112, where it is judged if the count C has become smaller than C_2. When $C < C_2$, the processing cycle is ended. Therefore, as shown in Fig. 9, the correction coefficient k is held constant until $C \geqq C_2$.

Next, at step 112, when it is judged that $C \geqq C_2$, the routine proceeds to step 113, where β is subtracted from the correction coefficient k. Next, at step 113, it is judged if the correction coefficient k has become zero or a negative number. When $k > 0$, the processing cycle is ended. Accordingly, as shown in Fig. 9, the correction coefficient k is reduced until $k \leqq 0$. Note that, as mentioned later, if $k > 0$, the air-fuel mixture fed to the combustion chamber 3 is made rich and during this time the degree of richness is changed by the pattern shown in Fig 9.

On the other hand, if it is judged at step 114 that $K \leq 0$, the routine proceeds to step 115, where the NO_x release flag is reset. Next, at step 116, ΣNO_x is made zero. That is, at this time, it is considered that all of the NO_x which had been absorbed in the NO_x absorbent 17 is released, so the estimated value ΣNO_x of the NO_x absorbed in the NO_x absorbent 17 is made zero. Next, at step 117, the count C and the correction coefficient k are made zero and the processing cycle is ended.

On the other hand, if it is judged at step 101 that $k \geqq 1.0$, that is, when the engine operating state is one in which the air-fuel mixture should be made rich or the stoichiometric air-fuel ratio, the routine proceeds to step 118, where the count D is incremented by one. Next, at step 119, it is judged if the count D has become larger than the constant value D_0. When $D > D_0$, the routine proceeds to step 120, where ΣNO_x is made zero. That is, when the combustion of the rich air-fuel ratio or the stoichiometric air-fuel ratio continues for a certain time, it may be considered that all of the NO_x has been released from the NO_x absorbent 17, so at this time the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 is made zero.

Figure 14 shows the routine for calculation of the fuel injection time TAU. This routine is repeatedly executed.

Referring to Fig. 14, first, at step 150, a basic fuel injection time TP is calculated from a map indicated in Fig. 2. Subsequently, at step 151, the correction coefficient K shown in Fig. 3, which is determined in accordance with the operating state of the engine, is calculated. Next, at step 152, it is judged if the NO_x release flag is set or not. When the NO_x release flag is not set, the routine proceeds to step 153, where the correction coefficient K is made K_t. Next, at step 155, K_t is multiplied with the basic fuel injection time TP, whereby the fuel injection time TAU is calculated. Accordingly, at this time, the air-fuel mixture which is fed into the combustion chamber 3 is made lean, the stoichiometric air-fuel ratio, or rich in accordance with the operating state of the engine as shown in Fig. 3.

On the other hand, when it is judged at step 152 that the NO_x release flag is set, the routine proceeds to step 154, where it is made the sum $(k+1)$ of correction coefficient k calculated by the routine shown in Fig. 12 and Fig. 13 and 1, then the routine proceeds to step 155. Next, at this time, the air-fuel mixture fed to the combustion chamber 3 is made rich, then the degree of richness is changed by the pattern shown in Fig. 9.

Figure 15 to Fig. 20 show a second embodiment. As mentioned earlier, in the first embodiment, when the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 exceeded the NO_x absorption capacity NO_xCAP of the NO_x absorbent 17, the air-fuel ratio of the air-fuel mixture fed to the combustion chamber 3 was switched from lean to rich and the NO_x was released from the NO_x absorbent 17, but further, even during engine high load operation and engine full load operation, a releasing action of the NO_x from the NO_x absorbent 17 is performed. In the second embodiment, even in engine operating states other than engine high load operation and engine full load operation, the air-fuel mixture is made rich and a NO_x release action from the NO_x absorbent 17 is performed. At this time, when all of the NO_x absorbed in the NO_x absorbent 17 is considered to have been released, the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 is made zero.

That is, in the first embodiment, as will be understood from Fig. 3, when an acceleration operation is performed in which the engine load is made to increase in the low load region, that is, when a gradual acceleration operation is performed, the air-fuel mixture is maintained lean, while when an acceleration operation is performed in which the engine load shifts from the low load to high load, that is, a rapid acceleration operation is performed, the air-fuel mixture is switched from lean to the stoichiometric air-fuel ratio. As opposed to this, in the second embodiment, during rapid acceleration operation, the air-fuel mixture is made a rich air-fuel mixture in accordance with the degree of acceleration to secure a good acceleration operation and at that time the NO_x release action is performed.

Further, when a shift down is performed in the automatic transmission 22, the engine rotational speed increases, but at this time, if there is a delay

in the increase of the engine rotational speed, a torque shock is produced when the shift down occurs. Therefore, in the second embodiment, when a shift down is performed, the air-fuel mixture is made rich to immediately raise the engine rotational speed and thereby the occurrence of a torque shock is inhibited. At this time too, the NO_x release action is performed.

Further, in the first embodiment, when the estimated value ΣNO_x of the NO_x absorbed in the NO_x absorbent 17 reaches the NO_x absorption capacity NO_xCAP shown in Fig. 7, the air-fuel mixture is switched from lean to rich and a NO_x release action is performed, but in the second embodiment, when the estimated value ΣNO_x of the NO_x absorbed in the NO_x absorbent 17 reaches 70 percent of the NO_x absorption capacity NO_xCAP shown in Fig. 7, the air-fuel mixture is switched from lean to rich and the NO_x release action is performed.

Further, in the second embodiment, during idling operation in which the throttle valve 14 is open for idling and during a deceleration operation, the air-fuel ratio of the air-fuel mixture fed to the combustion chamber 3 is made the stoichiometric air-fuel ratio. However, when the air-fuel mixture is made rich to cause the NO_x to be released, it takes less in fuel consumption and there is less fluctuation in the torque if the air-fuel ratio of the air-fuel mixture is switched between the stoichiometric air-fuel ratio and rich rather than if the air-fuel ratio of the air-fuel mixture is switched between lean and rich. Accordingly, in the second embodiment, to increase the opportunities for causing the NO_x to be released by switching the air-fuel ratio of the air-fuel mixture from the stoichiometric air-fuel ratio to rich, in the case where the estimated value ΣNO_x of the amount of the NO_x absorbed in the NO_x absorbent 17 exceeds 30 percent of the NOx absorption capacity NO_xCAP shown in Fig. 7, when the throttle valve 14 is open in the idling position, the air-fuel mixture is temporarily made rich to perform the NO_x release action. In this case, if the NO_x release action is ended, the air-fuel mixture is maintained at the stoichiometric air-fuel ratio.

Next, an explanation will be made of a second embodiment of the control of release of NO_x with reference to Fig. 15 to Fig. 19.

Figure 15 and Fig. 16 show a time interruption routine executed by interruption every predetermined time.

Referring to Fig. 15 and Fig. 16, first, at step 200, it is judged if a NO_x release flag showing that the NO_x should be released from the NO_x absorbent 17 is set or not. When the NO_x release flag is not set, the routine proceeds to step 201, where it is judged if the correction coefficient K is smaller than 1.0, that is, if the operating state is one in which the air-fuel mixture should be made lean. When $K < 1.0$, that is, when the operating state is one in which the air-fuel mixture should be made lean, the routine proceeds to step 202.

At step 202, the NO_x amount Nij discharged from the engine per unit time is calculated from the map shown in Fig. 6(B) based on the absolute pressure PM in the surge tank 10, detected by the pressure sensor 19, and the engine rotational speed N. Next, at step 203, the NO_x amount Nij is multiplied by the interruption time interval Δt and the product $Nij \cdot \Delta T$ is added to ΣNO_x. The product $Nij \cdot \Delta t$ shows the estimated value of the amount of the NO_x absorbed in the NO_x absorbent 17. Next, at step 204, it is judged if the estimated value ΣNO_x of the amount of the NO_x absorbed in the NO_x absorbent 17 is greater than 30 percent CAP, that is, 30 percent of the NO_x absorption capacity NO_xCAP shown in Fig. 7. When $\Sigma NO_x \leq 30$ percent CAP, the routine proceeds to step 205, where the enable flag is reset, then the processing cycle is ended. As opposed to this, when $\Sigma NO_x > 30$ percent CAP, the routine proceeds to step 206, where the enable flag is set, then the routine proceeds to step 207.

At step 207, it is judged if the estimated value ΣNO_x of the amount of the NO_x absorbed in the NO_x absorbent 17 is greater than 70 percent CAP, that is, 70 percent of the NO_x absorption capacity NO_xCAP shown in Fig. 7. When $\Sigma NO_x \leq 70$ percent CAP, the processing cycle ends.

On the other hand, if it is judged at step 207 that $\Sigma NO_x > 70$ percent CAP, that is, if it is judged that over 70 percent of the NO_x of the NO_x absorption capacity is absorbed in the NO_x absorbent 17, the routine proceeds to step 208, where the NO_x release flag is set. Next, at step 209, C_1, C_2, α, and β are calculated from the relationship shown in Fig. 10 on the basis of the temperature T of the exhaust gas and the processing cycle ends. If the NO_x release flag is set, at the next processing cycle, the routine proceeds from step 200 to step 210, where the count is incremented by one. Next, at step 111, it is judged if the count C is smaller than C_1. When $C < C_1$, the routine proceeds to step 212, α is added to the correction coefficient k. Next, the processing cycle ends. The action of addition of α to the correction coefficient k is performed continuously until $C \geq C_1$. Accordingly, the value of the correction coefficient k continues to increase during this period as shown in Fig. 9.

On the other hand, if it is judged at step 211 that $C \geq C_1$, the routine proceeds to step 213, where it is judged if the count C has become smaller than even C_2. When $C < C_2$, the processing cycle ends. Therefore, as shown in Fig. 9, the correction coefficient k is held constant until $C \geq C_2$.

Next, if it is judged at step 213 that $C \geq C_2$, the routine proceeds to step 214, where β is subtracted from the correction coefficient k. Next, at step 215, it is judged if the correction coefficient k has become zero or a negative number. When k > 0, the processing cycle ends. Therefore, as shown in Fig. 9, the correction coefficient k is reduced until k ≦ 0. Note that as mentioned later, when k > 0, the air-fuel mixture fed into the combustion chamber 3 is made rich and during this time the degree of richness is changed by the pattern shown in Fig. 9.

On the other hand, if it is judged at step 215 that k ≦ 0, the routine proceeds to step 216, where the NO_x release flag is reset. Next, at step 217, ΣNO_x is made zero. That is, at this time, it is considered that all of the NO_x which had been absorbed in the NO_x absorbent 17 has been released, so the estimated valve ΣNO_x of the NO_x absorbed in the NO_x absorbent 17 is made zero. Next, at step 218, the count C and the correction coefficient k are made zero and the processing cycle is ended.

On the other hand, if it is judged at step 201 that k ≧ 1.0, that is, the engine operating state is one in which the air-fuel mixture should be made rich or the stoichiometric air-fuel ratio, the routine proceeds to step 219, where it is judged if the vehicle speed V is greater than a constant value, for example, 130 km/h, from the output signal of the vehicle speed sensor 24. If the operation is performed so that the vehicle speed V exceeds 130 km/h, the NO_x is completely released from the NO_x absorbent 17, so at this time the routine proceeds to step 221, where the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 is made zero. As opposed to this, when V ≦ 130 km/h, the routine proceeds to step 220, where it is judged if a predetermined time has past from when k ≧ 1.0. When a predetermined time has past, the routine proceeds to step 221, where ΣNO_x is made zero. That is, when the combustion of a rich air-fuel mixture or an air-fuel mixture with a stoichiometric air-fuel ratio continues for a predetermined time, it is considered that all the NO_x has been released from the NO_x absorbent 17, so at this time, the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 is made zero.

Figure 17 to Fig. 19 show the routine for calculating the fuel injection time TAU. This routine is repeatedly executed.

Referring to Fig. 17 to Fig. 19, first, at step 250, the basic fuel injection time TP is calculated from the map shown in Fig. 2. Next, at step 251, the correction coefficient K shown in Fig. 3, determined in accordance with the operating state of the engine, is calculated. Next, at step 252, it is judged if the throttle valve 14 is open for idling on the basis of the output signal of the idle switch 20. When the throttle valve 14 is not open for idling, the routine proceeds to step 261, where the rich flag is reset, then the routine proceeds to step 262.

At step 262, it is judged if the correction coefficient K is smaller than 1.0. When K ≧ 1.0, that is, when the air-fuel ratio of the air-fuel mixture should be made rich or the stoichiometric air-fuel ratio, the routine jumps to step 268. As opposed to this, when K ≦ 1.0, that is, when the air-fuel ratio of the air-fuel mixture should be made lean, the routine proceeds to step 263, where the pressure difference ΔPM between the current absolute pressure PM in the surge tank 10 and the absolute pressure PM_1 in the surge tank 10 which is detected in the previous processing cycle is calculated. Next, at step 264, it is judged if the pressure difference ΔPM is larger than a constant value X_0, that is, if a rapid acceleration operation is underway. When $\Delta PM \leq X_0$, that is, when a rapid acceleration operation is not underway, the routine proceeds to step 268.

At step 268, it is judged if a shift down action of the automatic transmission is being performed on the basis of the output signal of the gear position detector 23. When a shift down action is not underway, the routine jumps to step 272. At step 272, it is judged if the NO_x release flag is set or not. When the NO_x release flag is not set, the routine proceeds to step 273, where the correction coefficient K is made K_t. Next, at step 275, K_t is multiplied with the basic fuel injection time TP, whereby the fuel injection time TAU is calculated. Accordingly, at this time, the air-fuel mixture fed into the combustion chamber 3 is made lean or the stoichiometric air-fuel ratio or rich in accordance with the operating state of the engine as shown in Fig. 3.

On the other hand, if it is judged at step 274 that the NO_x release flag is set, the routine proceeds to step 274, where K_t is made the sum of the correction coefficient k calculated by the routine shown in Fig. 15 and Fig. 16 and 1, then the routine proceeds to step 275. Therefore, at this time, the air-fuel mixture fed into the combustion chamber 3 is made rich. At this time, the degree of richness is changed by the pattern shown in Fig. 9.

On the other hand, when it is judged at step 252 that the throttle valve 14 is open in the idling position, the routine proceeds to step 253, where it is judged if the rich flag is set or not. If the rich flag is not set, the routine proceeds to step 254, where it is judged if the enable flag is set or not. When the enable flag is set, the routine proceeds to step 255, where the rich flag is set, then at step 256, the correction coefficient K_t is made 1.2. Next, the routine proceeds to step 275. As opposed to this,

when the enable flag is not set, the routine proceeds to step 260, where the correction coefficient K_t is made 1.0. then the routine proceeds to step 275.

Accordingly, when the throttle valve 14 is open to the idling position, if the enable flag is set, that is, when over 30 percent of the NO_x absorption capacity NO_xCAP of the NO_x is absorbed in the NO_x absorbent 17, the air-fuel mixture is made rich. At this time, when the amount of NO_x absorbed in the NO_x absorbent 17 is less than 30 percent of the NOx absorption capacity NO_xCAP, the air-fuel ratio of the air-fuel mixture is made the stoichiometric air-fuel ratio.

If the rich flag is set, the routine proceeds from step 253 to step 257, where it is judged if a predetermined time has elapsed since the rich flag has been set. When the predetermined time has elapsed, the routine proceeds to step 258, where the rich flag is reset, then at step 259 the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 is made zero. Next, at step 260, the correction coefficient K_t is made 1.0. If the ΣNO_x is made zero at step 259, the enable flag is reset in the routine shown in Fig. 15 and Fig. 16, so at the next processing cycle, the routine proceeds through steps 253 and 254 to step 260. Therefore, when the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 is over 30 percent of the NO_x absorption capacity NO_xCAP, the air-fuel mixture is temporarily made rich, then the air-fuel ratio of the air-fuel mixture is made the stoichiometric air-fuel ratio.

On the other hand, if it is judged at step 264 that $\Delta PM > X_0$, that is, during a rapid acceleration operation, the routine proceeds to step 265, where the correction coefficient K_t is calculated from the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 on the basis of the relationship shown in Fig. 20. As shown in Fig. 20, the correction coefficient K_t is larger than 1 and the correction coefficient K_t becomes larger the larger the estimated value ΣNO_x. Accordingly, if a rapid acceleration operation is performed, the air-fuel mixture is made rich. Next, at step 266, it is judged if a predetermined time has elapsed since $\Delta PM > X_0$. If the predetermined time has elapsed, the routine proceeds to step 267, where the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 is made zero.

On the other hand, when it is judged at step 268 that a shift down action is underway at the automatic transmission 22, the routine proceeds to step 269, where the correction coefficient K_t is made 1.2. Therefore, when a shift down action is performed, it is understood, the air-fuel mixture immediately is made rich. Next, at step 270 it is judged if a predetermined time has elapsed from when the shift down action was started. When a predetermined time has elapsed, the routine proceeds to step 271, where the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 is made zero.

Note that if the air-fuel mixture is made rich for a certain time to release the NO_x, then the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 is made zero at steps 259, 267, and 271, but at this time it is also possible not to make the estimated value ΣNO_x zero, but to make the estimated value ΣNO_x about 30 percent or lower of the NO_x absorption capacity NO_xCAP.

Figure 21 shows another embodiment of the internal combustion engine. In this embodiment, an outlet side of a casing 18 is connected through an exhaust pipe 27 to a catalytic converter 29 housing a three-way catalyst. This three-way catalyst 28, as is well known, exhibits a high purification efficiency with respect to CO, HC, and NO_x when the air-fuel ratio is maintained near the stoichiometric air-fuel ratio, but the three-way catalyst 28 also has a high purification efficiency with respect to NO_x even when the air-fuel ratio becomes rich to a certain extent. In the embodiment shown in Fig. 21, a three-way catalyst 28 is provided downstream of the NO_x absorbent 17 so as to remove the NO_x using this characteristic.

That is, as is mentioned above, if the air-fuel mixture fed into the engine cylinder is made rich to release the NO_x from the NO_x absorbent 17, the NO_x absorbed in the NO_x absorbent 17 is rapidly released from the NO_x absorbent 17. At this time, the NO_x is reduced during its release, but there is a possibility that all of the NO_x will not be reduced. If the three-way catalyst 28 is disposed downstream of the NO_x absorbent 17, however, the NO_x which could not be reduced at the time of the release of the NO_x is reduced by the three-way catalyst 28. Accordingly, by disposing the three-way catalyst 28 downstream of the NO_x absorbent 17, it becomes possible to improve considerably the purification performance of the NO_x.

In the embodiments discussed up to here, use was made, as the NO_x absorbent, of a NO_x absorbent 17 comprised of at least one of an alkali metal, alkali earth, and rare earth and a precious metal carried on alumina. Instead of using such a NO_x absorbent 17, however, it is also possible to use a complex oxide of an alkali earth and copper, that is, a NO_x absorbent of the Ba-Cu-O system. As such a complex oxide of an alkali earth and copper, use may be made for example of $MnO_2 \cdot BaCuO_2$. In this case, it is also possible to add platinum Pt or cerium Ce. In a NO_x absorbent of the $MnO_2 \cdot BaCuO_2$ system, the copper Cu per-

forms the same catalytic function as the platinum Pt in the NO_x absorbent 17 spoken of up to now. When the air-fuel ratio is lean, the NO_x is oxidized by the copper ($2NO + O_2 \rightarrow 2NO_2$) and dispersed in the absorbent in the form of nitric acid ions NO_3^-.

On the other hand, if the air-fuel ratio is rich, similarly, NO_x is released from the absorbent. This NO_x is reduced by the catalytic action of the copper Cu. The NO_x reducing ability of copper Cu, however, is weaker than the NO_x reducing ability of platinum Pt and therefore when using an absorbent of the Ba-Cu-O system, the amount of NO_x which is not reduced at the time of release of the NO_x becomes somewhat greater than with the NO_x absorbent 17 discussed up to now. Therefore, when using an absorbent of the Ba-Cu-O system, as shown in Fig. 21, it is preferable to dispose a three-way catalyst 28 downstream of the absorbent.

Figure 22 and Fig. 27 show the case of application of the present invention to a diesel engine. Note that in Fig. 22 and Fig. 27, constituent elements the same as those in Fig. 1 are given the same reference numerals.

In a diesel engine, usually, during all operating states, combustion is performed with an air excess rate of over 1.0, that is, with the average air-fuel ratio of the air-fuel mixture in the combustion chamber 3 in a lean state. Accordingly, at this time, the NO_x which is discharged is absorbed in the NO_x absorbent 17. On the other hand, when NO_x is to be released from the NO_x absorbent 17, hydrocarbons are fed into the engine exhaust passage upstream of the NO_x absorbent 17, whereby the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent 17 becomes rich.

Referring to Fig. 22, in this embodiment, provision is made of a load sensor 51 which generates an output voltage proportional to the amount of depression of the accelerator pedal 50. The output voltage of the load sensor 51 is input to the input port 35 through an AD converter 40. Further, in this embodiment, an intake shutoff valve 52 is disposed in the intake duct 12, which intake shutoff valve 52 is connected to a diaphragm 54 of the vacuum diaphragm apparatus 53. The diaphragm vacuum chamber 55 of the vacuum diaphragm apparatus 53 is connected selectively to the atmosphere or a vacuum tank 57 through a solenoid switching valve 56. On the other hand, the output port 36 of the electronic control unit 30 is connected through a corresponding drive circuit 39 to a solenoid switching valve 56. The diaphragm vacuum chamber 55 is usually open to the atmosphere. At this time, the intake shutoff valve 52 is held in the fully open position as shown in Fig. 22.

Further, a reducing agent feed valve 58 is disposed in the exhaust pipe 16, which reducing agent feed valve 58 is connected through a feed pump 59 to a reducing agent tank 60. The output port 36 of the electronic control unit 30 is connected through the corresponding drive circuit 39 to the reducing agent feed valve 58 and the feed pump 59. Inside the reducing agent tank 60 is filled a hydrocarbon such as gasoline, isooctane, hexane, heptane, gas oil, and kerosine or a hydrocarbon which can be stored in a liquid form, such as butane or propane.

In the diesel engine shown in Fig. 22 too, the amount of the NO_x which is absorbed in the NO_x absorbent 17 is estimated from the amount of NO_x in the exhaust gas discharged from the engine. That is, in the diesel engine as well, the higher the engine rotational speed N, the greater the amount of the exhaust gas discharged per unit time from the engine, so along with a rise in the engine rotational speed N, the amount of NO_x discharged per unit time from the engine increases. Further, the higher the engine load, that is, the greater the amount of depression of the accelerator pedal 50, the greater the amount of exhaust gas discharged from the combustion chambers 3 and further the higher the combustion temperature, so the higher the engine load, that is, the greater the amount of depression of the accelerator pedal 50, the greater the amount of the NO_x discharged per unit time from the engine.

Figure 23(A) shows the relationship between the amount of NO_x discharged from an engine per unit time, the amount of depression Acc of the accelerator pedal 50, and the engine rotational speed N, found by experiments. In Fig. 23(A), the curves show the same amounts of NO_x. As shown in Fig. 23(A), the amount of NO_x which is discharged from the engine per unit time increases along with an increase in the amount of depression Acc of the accelerator pedal 50 and increases along with an increase in the engine rotational speed N. Note that the amount of NO_x shown in Fig. 23(A) is stored in the ROM 32 in advance in the form of a map shown in Fig. 23(B).

In a diesel engine, the air-fuel mixture inside the combustion chamber 3 is made to burn in an excessive air state, that is, in a state with the average air-fuel ratio lean. At this time, the NO_x discharged from the engine is absorbed in the NO_x absorbent 17. Figure 24 shows the relationship between the amount of NO_x absorbed in the NO_x absorbent 17 and the concentration of NO_x in the exhaust gas flowing out from the NO_x absorbent 17. Further, in Fig. 24, the amount of absorption A of the NO_x shows the allowable absorption limit amount below which the NO_x absorbent 17 can absorb NO_x well.

As will be understood from Fig. 24, when the amount NO_x absorption is smaller than the allowa-

ble absorption limit amount A, all of the NO_x in the exhaust gas is absorbed in the NO_x absorbent 17, so at this time the concentration of the NO_x in the exhaust gas flowing out from the NO_x absorbent 17 becomes zero. As opposed to this, if the amount of absorption of NO_x exceeds the allowable absorption limit amount A, the NO_x absorption rate gradually falls along with the increase of the amount of absorption of NO_x, therefore the concentration of NO_x in the exhaust gas flowing out from the NO_x absorbent 17 gradually becomes higher. At this time, if the amount of NO_x in the exhaust gas flowing into the NO_x absorbent 17 is made H_1 (=1.0), then of the NO_x, only K_1/H_1 (= K_1) is absorbed by the NO_x absorbent 17.

On the other hand, in this embodiment, when a deceleration operation is performed, the NO_x release action is performed. That is, when a deceleration operation is performed, the diaphragm vacuum chamber 55 is connected to the vacuum tank 57 by the switching action of the switching valve 56, whereby the intake shutoff valve 52 is made to close to close to the fully closed position. If the feed pump 61 is driven at the same time, the reducing agent feed valve 58 is made to open, whereby the hydrocarbons filled in the reducing agent tank 60 are fed from the reducing agent feed valve 58 to the inside the exhaust pipe 16. The amount of the hydrocarbons fed at this time is determined so that the air-fuel ratio of the inflowing exhaust gas flowing into the NO_x absorbent 17 becomes rich. Accordingly, at this time, the NO_x is released from the NO_x absorbent 17.

If the intake shutoff valve 52 is made to close in this way, the amount of exhaust gas discharged from the engine falls and therefore a small amount of reducing agent is fed, whereby the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent 17 is made rich. That is, when the NO_x release action is performed, it is possible to close the intake shutoff valve 52 to reduce the amount of consumption of the reducing agent. Further, the only time when there is no effect on the operating state of the engine even when the intake shutoff valve 52 is closed is during deceleration operation. Further, at this time, if the intake shutoff valve 52 is made to close, the engine brake acts powerfully. Accordingly, in the embodiment according to the present invention, the intake shutoff valve 52 is closed at the time of deceleration operation and at that time the NO_x release action is performed.

Figure 25 shows the residual rate of the NO_x which continues to remain in the NO_x absorbent 17 after the start of the release of the NO_x. As shown by the solid line in Fig. 25, if the NO_x release action is started, the NO_x residual rate gradually falls. In this case, as shown by the solid line in Fig. 25, the residual amount does not fall uniformly along with the passage of time, but the residual amount of NO_x falls relatively fast in the early part of the NO_x release action and falls relatively gently at the latter part of the same. Further, when use is made of a reducing agent with a relatively low volatility, such as gas oil or kerosine, it takes time for the reducing agent to vaporize, so as shown by the broken line in Fig. 25, even if the reducing agent is fed, the NO_x release action will not be performed immediately and therefore time will be taken until all of the NO_x is released.

As will be understood from Fig. 25, if the NO_x release action is performed for about the time t_0, substantially all the NO_x is released from the NO_x absorbent 17. Therefore, in the embodiment according to the present invention, when a deceleration operation is started, the intake shutoff valve 52 is made to close over the time t_0 and the reducing agent is fed into the exhaust pipe 16 over the time t_0. However, if the period of the deceleration operation is short, the NO_x release action ends up stopped before the NO_x residual rate becomes zero. In such a case, if it is judged that the release action of all of the NO_x has ended, then when the estimated value ΣNO_x of the NO_x absorbed in the NO_x absorbent 17 reaches the allowable absorption limit amount A (Fig. 24). if it is attempted to perform the NO_x release action once again, then the absorption ability of the NO_x absorbent 17 will end up becoming saturated before the NO_x release action is performed and therefore a large amount of NO_x will be released into the atmosphere.

However, when the period of the deceleration operation is short and therefore the NO_x residual rate does not become zero, if the NO_x residual rate just before the start of the deceleration operation is made H_2 (=1.0), then the NO_x residual rate when the NO_x release action is ended is expressed by K_2/H_2 (= K_2). Accordingly, in the embodiment according to the present invention, when not all of the NO_x has been released when releasing the NO_x, it is estimated that the amount of NO_x of $K_2 \cdot \Sigma NO_x$ continues to remain in the NO_x absorbent 17 and the next performed NO_x release period is made earlier.

Next, an explanation will be given of the control of the release of NO_x referring to Fig. 26. Note that the NO_x release control routine shown in Fig. 26 is executed by interruption every predetermined time period.

Referring to Fig. 26, first, at step 300, the amount Nij of NO_x discharged from the engine per unit time is calculated from the map shown in Fig. 23(B) based on the amount of depression of the accelerator pedal 50 and the engine rotational speed N. Next, at step 301, it is judged if the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 has exceeded the

allowable absorption limit A (Fig. 24). When $\Sigma NO_x \leq A$, the routine proceeds to step 302, where the interruption time interval Δt is multiplied with the amount Nij of the NO_x. The product $Nij \cdot \Delta t$ is added to ΣNO_x. The product $Nij \cdot \Delta t$ expresses the amount of NO_x discharged from the engine in the period of the interruption time interval Δt and therefore ΣNO_x expresses the estimated value of the amount of NO_x absorbed in the NO_x absorbent 17. Next, at step 303, the execution enable flag F_1 for enabling execution of the NO_x release action is reset, then the routine proceeds to step 306.

On the other hand, when it is judged at step 301 that $\Sigma NO_x > A$, the routine proceeds to step 304, where the product $K_1 \cdot Nij \cdot \Delta t$ obtained by multiplying K_1 (Fig. 24) with $Nij \cdot \Delta t$ is added to ΣNO_x. Next, the routine proceeds to step 305, where the execution enable flag is set, then the routine proceeds to step 306. At step 306, it is judged if the execution enable flag has been set. If the execution enable flag has not been set, the routine proceeds to step 314, where the count T is made zero, then the processing cycle is ended.

On the other hand, if it is judged at step 306 that the execution enable flag has been set, the routine proceeds to step 307, where it is judged if the conditions for the NO_x release action, that is, the conditions for regeneration of the NO_x, stand or not. In this case, when the amount of depression of the accelerator pedal 50 is zero and the engine rotational speed N is higher than a predetermined rotational speed, that is, during deceleration operation, it is judged that the conditions for regeneration of the NO_x absorbent 17 stand. Note that in this case, it is possible to add to the conditions of regeneration that the temperature of the exhaust gas be at least a temperature able to make the temperature of the NO_x absorbent 17 the activation temperature.

When it is judged at step 307 that the regeneration conditions stand, the routine proceeds to step 308, where the NO_x is regenerated. That is, the intake shutoff valve 52 is made to close and the reducing agent is fed from the reducing agent feed valve 58. Next, at step 309, the interruption time interval Δt is added to the count T. Next, at step 310, it is judged if the time T elapsed since the start of regeneration has exceeded t_0 (Fig. 25). When $T < t_0$, the processing cycle is ended. As opposed to this, when $T \geq t_0$, the regeneration action of the NO_x absorbent 17 is stopped, then the routine proceeds to step 312, where the estimated amount ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 is made zero. Next, the routine proceeds through step 314, whereafter the processing cycle is ended.

On the other hand, when the regeneration conditions no longer stand, the routine proceeds to step 311, where it is judged if the time T elapsed from the start of the regeneration exceeds a predetermined time t_A. The predetermined time t_A is a time somewhat shorter than t_0 as shown in Fig. 25 and expresses a time wherein it can be deemed that the NO_x residual rate is zero. Accordingly, when $T > T_A$, the routine proceeds to step 312, where the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 is made zero.

As opposed to this, when it is judged at step 311 that $T \leq t_A$, that is, when the period of the deceleration operation is short and NO_x continues to remain in the NO_x absorbent 17, the routine proceeds to step 313, where the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 is deemed to be ΣNO_x multiplied by K_2 (Fig. 25). Accordingly, in the next interruption routine, at step 302, $Nij \cdot \Delta t$ is added to ΣNO_x.

In the embodiment shown in Fig. 27, a NO_x concentration sensor 62 is disposed in the exhaust passage 60 downstream of the NO_x absorbent 17. This NO_x concentration sensor 62 generates an output voltage proportional to the NO_x concentration in the exhaust gas discharged from the NO_x absorbent 17, which output voltage is input through an AD converter 41 to the input port 35. Further, the output port 36 is connected through a corresponding drive circuit 39 to a warning lamp 63.

In this embodiment too, basically, when the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 exceeds the allowable limit amount A, if the conditions for regeneration stand, the NO_x is regenerated. Further, in this embodiment, if it is detected that the absorbing ability of the NO_x absorbent 17 has fallen due to the fact that the amount of NO_x actually absorbed is greater than the estimated value ΣNO_x, the NO_x absorbent 17 has deteriorated, or some other reason and the absorbing ability of the NO_x absorbent 17 falls, the regeneration action of the NO_x absorbent 17 is promoted by prolonging the regeneration period of the NO_x absorbent 17.

Next, an explanation will be made of the control for the release of NO_x referring to Fig. 28 to Fig. 30. Note that the NO_x release control routine shown from Fig. 28 to Fig. 30 is executed by interruption every predetermined time.

Referring to Fig. 28 to Fig. 30, at step 400, the amount Nij of the NO_x discharged from the engine per unit time is calculated from the map shown in Fig. 23(B) on the basis of the amount of depression of the accelerator pedal 50 and the engine rotational speed N. Next, at step 401, it is judged if the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 has exceeded the allowable limit amount A (Fig. 24). When $\Sigma NO_x \leq A$, the routine proceeds to step 402, where the

interruption time interval Δt is multiplied with the amount Nij of the NO_x. This product Nij$\cdot\Delta t$ is added to ΣNO_x. The product Nij$\cdot\Delta t$ expresses the amount of NO_x discharged from the engine in the period of the interruption time interval Δt and accordingly ΣNO_x expresses the estimated amount of the amount of NO_x absorbed in the NO_x absorbent 17. Next, at step 403, the execution flag F_1 for enabling execution of the NO_x release action is reset, then the routine proceeds to step 415.

On the other hand, it is judged at step 401 that $\Sigma NO_x > A$, the routine proceeds to step 404, where the NO_x concentration NOR detected by the NO_x concentration sensor 62 is read. Next, at step 405, it is judged if the NO_x concentration NOR is larger than a predetermined value W_0. When NOR $\leq W_0$, the NO_x has not deteriorated and therefore it is considered that an amount of NO_x as estimated is absorbed in the NO_x absorbent 17, so the routine proceeds to step 406, where the regeneration promotion flag F_2 showing that the regeneration of the NO_x absorbent 17 should be promoted is reset. Next, at step 407, the count C is made zero, then at step 408, the product $K_1\cdot$Nij$\cdot\Delta t$ obtained by multiplying K_1 (Fig. 24) with Nij$\cdot\Delta t$ is added to ΣNO_x Next, the routine proceeds to step 409, where the execution enable flag is set, then the routine proceeds to step 415. At step 415, it is judged if the execution enable flag is set. If the execution enable flag is not set, the routine proceeds to step 423, where the count T is made zero, then the processing cycle is ended.

On the other hand, if it is judged at step 415 that the execution enable flag is set,the routine proceeds to step 416, where it is judged if the condition for the NO_x release action, that is, the conditions for regeneration of the NO_x absorbent 17, stand. In this case, when the amount of depression of the accelerator pedal 50 is zero and the engine rotational speed N is higher than a predetermined rotational speed, as mentioned earlier, that is. during deceleration operation, it is judged that the conditions for regeneration of the NO_x absorbent 17 stand.

When it is judged at step 416 that the conditions for regeneration stand, the routine proceeds to step 417, where it is judged if the regeneration promotion flag is set. When the regeneration promotion flag is not set, the routine proceeds to step 148, where the NO_x absorbent 17 is regenerated. That is, the intake shutoff valve 52 is made to close and the reducing agent is fed from the reducing agent feed valve 58. Next, at step 419, the interruption time interval Δt is added to the count T. Next, at step 420, it is judged if the time T elapsed from the start of the regeneration exceeds t_0 (Fig. 25). When $T < t_0$, the processing cycle is ended. As opposed to this, when $T \geq t_0$, the regeneration action of the NO_x absorbent 17 is stopped and the routine proceeds to step 422, where the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x is made zero. Next, the routine proceeds through step 423 and the processing cycle is ended.

On the other hand, when the regeneration conditions no longer stand, the routine proceeds to step 416, where it is judged if the time T elapsed from the start of regeneration exceeds a predetermined time t_A. This predetermined time t_A is a time somewhat shorter than t_0 and expresses the time during which the NO_x residual rate is deemed to be zero, as mentioned earlier. Therefore, when $T > t_A$, the routine proceeds to step 422, where the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 is made zero.

As opposed to this, when it is judged at step 421 that $T \leq t_A$, that is, when the period of the deceleration operation is short and the NO_x continues to remain in the NO_x absorbent 17, the routine proceeds to step 424, where the estimated value ΣNO_x of the amount of the NO_x absorbed in the NO_x absorbent 17 is deemed to be the product of the multiplication of K_2 (Fig. 25) with ΣNO_x.

On the other hand, if it is judged at step 405 that NOR $> W_0$, that is, if it is judged that the NO_x concentration is high, the routine proceeds to step 410, where the regeneration promotion flag F_2 is set, then at step 411, the count C is incremented by one. Next, at step 412, it is judged if the count C has become larger than the predetermined value C_0. When $C \leq C_0$, the routine proceeds to step 408. Next, the routine proceeds through step 409 and 415 to step 416.

Next, if it is judged at step 416 that the regeneration conditions stand, the routine proceeds through step 417 to step 405, where the processing for promotion of regeneration is performed. In this processing of promotion of regeneration, for example, the voltage applied to the feed pump 59 is made to increase and the amount of feed of the reducing agent is made to increase. Alternatively, a burner (not shown) is disposed in the exhaust passage upstream of the NO_x absorbent 17 and the temperature of the exhaust gas is raised by the burner. Next, at step 426, the interruption time interval Δt is added to the count T, then at step 427, it is judged if the time T elapsed from the start of the regeneration promotion processing has become greater than a predetermined time t_1. This predetermined time t_1 is a time longer than t_0 at step 420. When $T \geq t_1$, the regeneration promotion processing of the NO_x absorbent 17 is stopped, then the routine proceeds to step 428, where the estimated value ΣNO_x of the amount of NO_x absorbed in the NO_x absorbent 17 is made zero.

So long as the NO_x absorbent 17 does not deteriorate and no abnormalities occur, if the regeneration promotion processing is performed once or the regeneration promotion processing is performed several times, when $\Sigma NO_x \geq A$ once again, it is judged at step 405 that $NOR \leq W_0$. If the NO_x absorbent 17 deteriorates or an abnormality occurs, however, even if the regeneration processing is performed several times, it is judged at step 405 that $NOR > W_0$, therefore at step 412 it is judged that $C > C_0$. In this case, the routine proceeds to step 413, where for example the regeneration execution flag F_1 is reset and wasteful regeneration processing is prohibited or other abnormality processing performed. Next, at step 414, for example, the warning lamp 63 is lit and the fact that an abnormality has occurred in the NO_x absorbent 17 is notified to the driver.

A NO_x absorbent (17) is disposed in an exhaust passage of an internal combustion engine. This NO_x absorbent (17) absorbs the NO_x when the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent (17) is lean and releases the absorbed NO_x when the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent (17) becomes rich. It estimates the amount of NO_x absorbed in the NO_x absorbent (17) from the engine load and the engine rotational speed and when the amount of the estimated NO_x becomes the maximum NO_x absorption capacity of the NO_x absorbent (17), makes the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent (17) rich.

LIST OF REFERENCE NUMERALS

3	combustion chamber
5	intake valve
7	exhaust valve
16	exhaust pipe
17	NO_x absorbent
25	temperature sensor

Claims

1. An exhaust purification device of an internal combustion engine which has in an engine exhaust passage a NO_x absorbent which absorbs NO_x when the air-fuel ratio of the inflowing exhaust gas is lean and which releases the absorbed NO_x when the oxygen concentration in the inflowing exhaust gas is reduced and which is provided with a NO_x estimating means for estimating the amount of the NO_x absorbed by the NO_x absorbent and a NO_x releasing means for reducing the oxygen concentration in the exhaust gas flowing into the NO_x absorbent and releasing NO_x from the NO_x absorbent when the amount of the NO_x estimated to be absorbed in the NO_x absorbent by the NO_x estimating means exceeds a predetermined allowable value.

2. An exhaust purification device of an internal combustion engine according to claim 1, wherein said NO_x estimating means estimates the NO_x absorbed in the NO_x absorbent on the basis of the amount of NO_x discharged from the combustion chamber to the engine exhaust passage.

3. An exhaust purification device of an internal combustion engine according to claim 2, wherein said NO_x estimating means is comprised of a NO_x calculating means for calculating the amount of NO_x discharged per unit time from the engine to the engine exhaust passage in accordance with the engine load and the engine rotational speed and an cumulative adding means for cumulatively adding the amounts of NO_x calculated by the NO_x calculating means.

4. An exhaust purification device of an internal combustion engine according to claim 3, wherein said NO_x calculating means is provided with a memory in which is previously stored the amount of NO_x discharged per unit time from the engine to the engine exhaust passage as a function of the engine load and the engine rotational speed and wherein the cumulative adding means cumulatively adds the amounts of NO_x stored in the memory and determined from the engine load and the engine rotational speed.

5. An exhaust purification device of an internal combustion engine according to claim 3, wherein provision is made of a throttle valve disposed in the engine intake passage for controlling the engine load and the vacuum inside the engine intake passage downstream of the throttle valve is used as a value representing the engine load.

6. An exhaust purification device of an internal combustion engine according to claim 3, wherein an accelerator pedal is provided for controlling the engine load and the amount of depression of the accelerator pedal is used as a value representing the engine load.

7. An exhaust purification device of an internal combustion engine according to claim 1, wherein said allowance is the maximum NO_x absorption capacity of the NO_x absorbent.

8. An exhaust purification device of an internal combustion engine according to claim 1, wherein said allowance is a predetermined amount of absorption smaller than the maximum NO_x absorption capacity of the NO_x absorbent.

9. An exhaust purification device of an internal combustion engine according to claim 1, wherein said allowance is a function of a temperature representing the temperature of the NO_x absorbent.

10. An exhaust purification device of an internal combustion engine according to claim 9, wherein the temperature representing the temperature of the NO_x absorbent is the temperature of the exhaust gas.

11. An exhaust purification device of an internal combustion engine according to claim 1, wherein said NO_x releasing means switches from lean to rich the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent in a predetermined time when the amount of the NO_x estimated by the NO_x estimating means exceeds the allowance.

12. An exhaust purification device of an internal combustion engine according to claim 11, wherein said NO_x releasing means switches from lean to rich the air-fuel ratio of the air-fuel mixture fed to the combustion chamber for a predetermined time when the amount of NO_x estimated by the NO_x estimating means exceeds the allowance.

13. An exhaust purification device of an internal combustion engine according to claim 11, which is provided with a reducing agent feeding means for feeding a reducing agent into the engine exhaust passage upstream of the NO_x absorbent and wherein said NO_x releasing means causes the reducing agent to be fed from said reducing agent feeding means into the engine exhaust passage upstream of the NO_x absorbent for a predetermined time when the amount of NO_x estimated by the NO_x estimating means exceeds the allowance.

14. An exhaust purification device of an internal combustion engine according to claim 13, wherein said reducing agent is comprised of a hydrocarbon.

15. An exhaust purification device of an internal combustion engine according to claim 14, wherein the hydrocarbon is at least one hydrocarbon selected from gasoline. isooctane, hexane, heptane, butane, propane, gas oil, and kerosine.

16. An exhaust purification device of an internal combustion engine according to claim 11, wherein said NO_x releasing means switches from lean to rich the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent in a predetermined time during a deceleration operation when the amount of the NO_x estimated by the NO_x estimating means exceeds the allowance.

17. An exhaust purification device of an internal combustion engine according to claim 16, wherein an intake shutoff valve which is normally fully open and is closed during deceleration operation is disposed inside the engine exhaust passage.

18. An exhaust purification device of an internal combustion engine according to claim 11, wherein said NO_x estimating means makes the amount of the NO_x estimated to be absorbed in the NO_x absorbent zero when the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent is made rich during the above predetermined time.

19. An exhaust purification device of an internal combustion engine according to claim 11, wherein said NO_x estimating means estimates that NO_x remains in the NO_x absorbent when the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent is made rich for a time shorter than the above predetermined time.

20. An exhaust purification device of an internal combustion engine according to claim 19, wherein said NO_x estimating means estimates the amount of the NO_x absorbed in the NO_x absorbent taking into consideration the amount of NO_x remaining in the NO_x absorbent.

21. An exhaust purification device of an internal combustion engine according to claim 19, wherein said NO_x estimating means causes the amount of the NO_x estimated to be remaining in the NO_x absorbent to increase the shorter the time in which the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent is made rich.

22. An exhaust purification device of an internal combustion engine according to claim 21, wherein provision is made of a memory which stores in advance the relationship between the

time during which the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent is made rich and the residual rate of the NO_x estimated to be remaining in the NO_x absorbent and wherein said NO_x estimating means estimates the amount of the NO_x remaining in the NO_x absorbent on the basis of the residual rate of the NO_x stored in the memory.

23. An exhaust purification device of an internal combustion engine according to claim 11, wherein a NO_x concentration detecting means is provided for detecting the concentration of NO_x in the exhaust gas flowing out from the NO_x absorbent and a NO_x release promoting means is provided for promoting the releasing action of the NO_x from the NO_x absorbent when the concentration of NO_x is higher than a predetermined concentration when the amount of the NO_x estimated by the NO_x estimating means exceeds the allowance.

24. An exhaust purification device of an internal combustion engine according to claim 23, wherein said NO_x release promoting means promotes the release action of NO_x by prolonging the time during which the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent is made rich.

25. An exhaust purification device of an internal combustion engine according to claim 23, wherein said NO_x release promoting means promotes the release action of NO_x by raising the degree of richness of the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent.

26. An exhaust purification device of an internal combustion engine according to claim 23, which is provided with a deterioration judging means for judging the NO_x absorbent is deteriorating when the concentration of NO_x is higher than a predetermined concentration when the amount of the NO_x estimated by said NO_x estimating means exceeds the allowance even when the promoting action of the release of said NO_x by the NO_x release promoting means has been performed more than a predetermined number of times.

27. An exhaust purification device of an internal combustion engine according to claim 1, wherein said NO_x estimating means estimates the amount of the NO_x absorbed in the NO_x absorbent taking into consideration the reduction in the NO_x absorption capacity when the NO_x absorption capacity of the NO_x absorbent has fallen.

28. An exhaust purification device of an internal combustion engine according to claim 27, wherein provision is made of a memory for storing in advance the relationship between the time in which the air-fuel ratio of the exhaust gas flowing into the NO_x absorbent 17 is made lean and the NO_x absorption capacity of the NO_x absorbent and wherein said NO_x estimating means estimates the amount of the NO_x absorbed in the NO_x absorbent on the basis of the NO_x absorption capacity stored in the memory.

29. An exhaust purification device of an internal combustion engine according to claim 1, wherein an air-fuel ratio control means is provided for making the air-fuel ratio of the air-fuel mixture fed to the combustion chamber rich in accordance with the operating state of the engine regardless of whether the amount of NO_x estimated by the NO_x estimating means exceeds the allowance.

30. An exhaust purification device of an internal combustion engine according to claim 29, wherein said air-fuel ratio control means makes the air-fuel ratio of the air-fuel mixture fed into the combustion chamber rich when the engine load is higher than a predetermined load.

31. An exhaust purification device of an internal combustion engine according to claim 29, wherein said air-fuel ratio control means makes the air-fuel ratio of the air-fuel mixture fed to the combustion chamber rich when shifting to idling operation.

32. An exhaust purification device of an internal combustion engine according to claim 29, wherein said air-fuel ratio control means makes the air-fuel ratio of the air-fuel mixture fed into the combustion chamber rich during an acceleration operation where the degree of acceleration is larger than a predetermined value.

33. An exhaust purification device of an internal combustion engine according to claim 29, wherein said air-fuel ratio control means makes the air-fuel ratio of the air-fuel mixture fed into the combustion chamber rich during a shift down action of the transmission.

34. An exhaust purification device of an internal combustion engine according to claim 29, wherein said NO_x estimating means makes the amount of NO_x estimated as being absorbed in

the NO_x absorbent zero when the air-fuel ratio of the air-fuel mixture is made rich for more than a predetermined time.

35. An exhaust purification device of an internal combustion engine according to claim 1, wherein the NO_x absorbent includes at least one substance selected from alkali metals such as potassium, sodium, lithium, and cesium, alkali earths such as barium and calcium, and rare earths such as lanthanum and yttrium and platinum.

36. An exhaust purification device of an internal combustion engine according to claim 1, wherein the NO_x absorbent is comprised of a compound oxide of barium and copper.

37. An exhaust purification device of an internal combustion engine according to claim 1, wherein a three-way catalyst is disposed in the engine exhaust passage downstream of the NO_x absorbent.

Fig.1

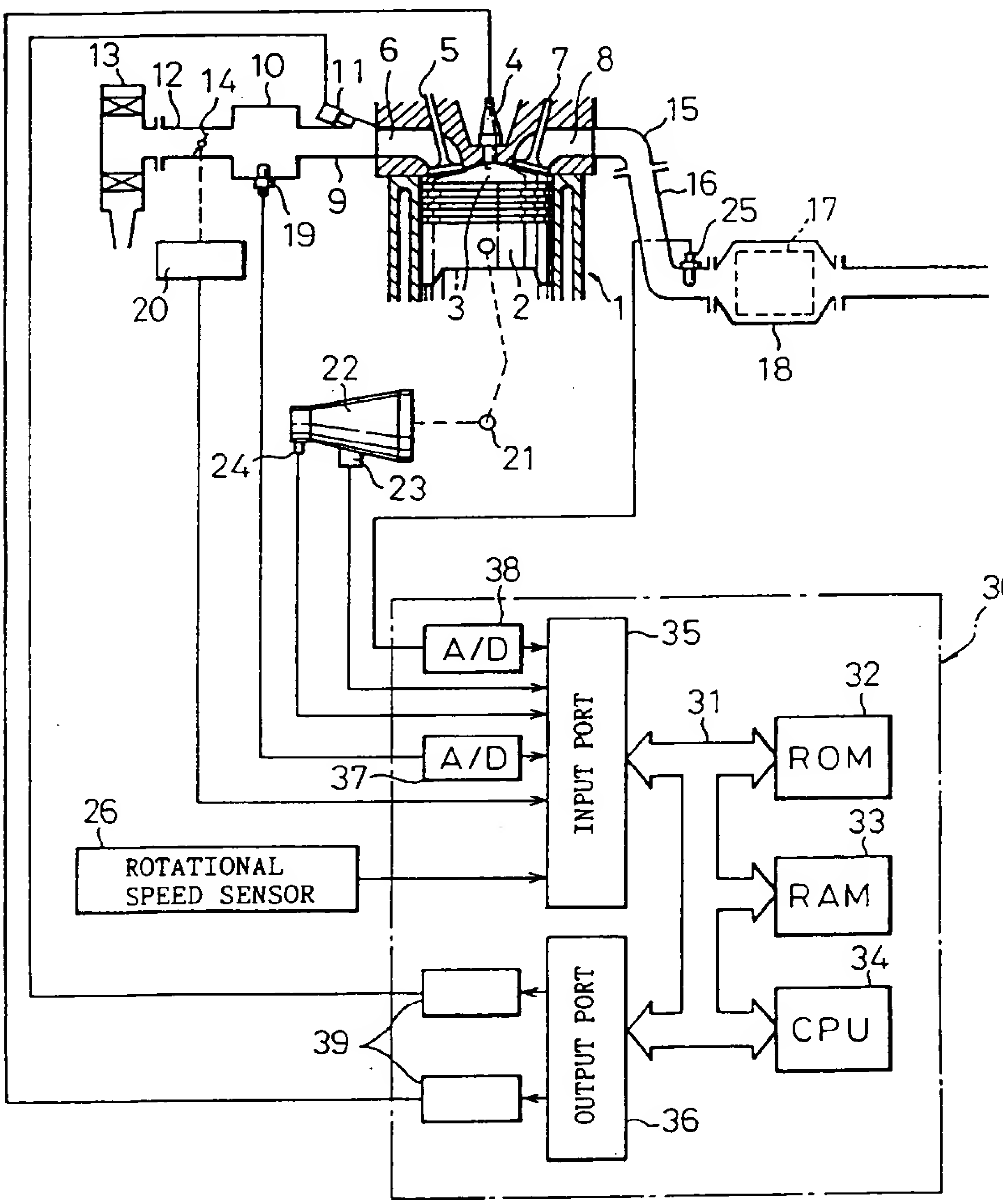

13
12
14
10
11
6
5
4
7
8
15
16
25
17
9
19
3
2
1
20
18
22
21
24
23
38
30
A/D
35
INPUT PORT
32
31
ROM
A/D
37
33
26
RAM
ROTATIONAL SPEED SENSOR
34
CPU
39
OUTPUT PORT
36

Fig.2

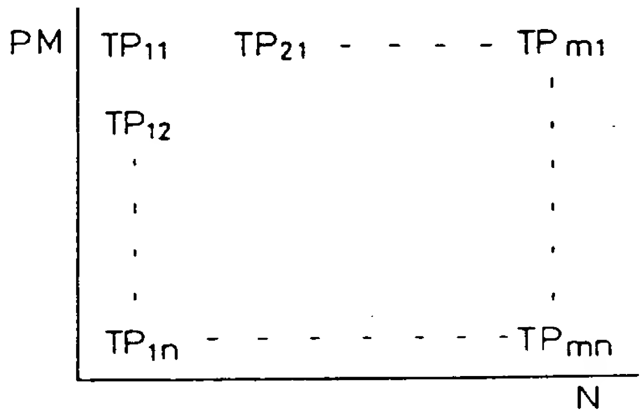

PM
TP11
TP21
TPm1
TP12
TP1n
TPmn
N

Fig.3

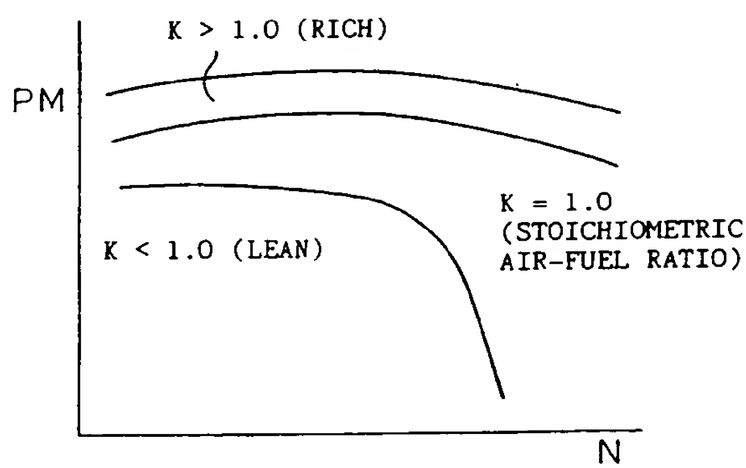

K > 1.0 (RICH)
PM
K = 1.0
(STOICHIOMETRIC
AIR-FUEL RATIO)
K < 1.0 (LEAN)
N

Fig.4

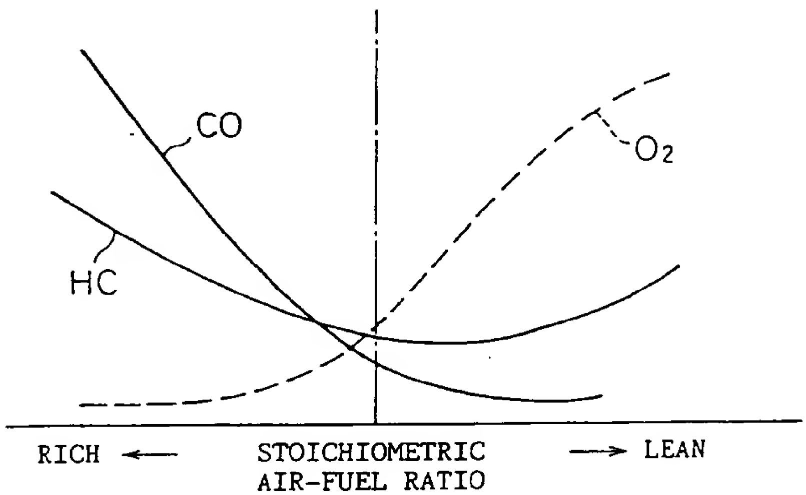


Fig.5(A)

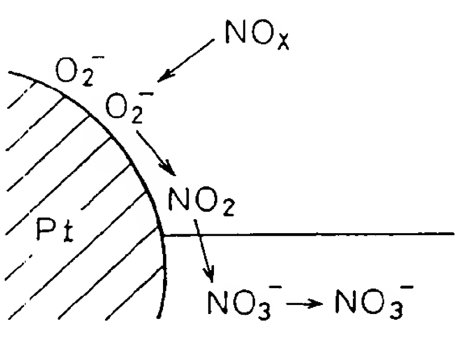


Fig.5(B)

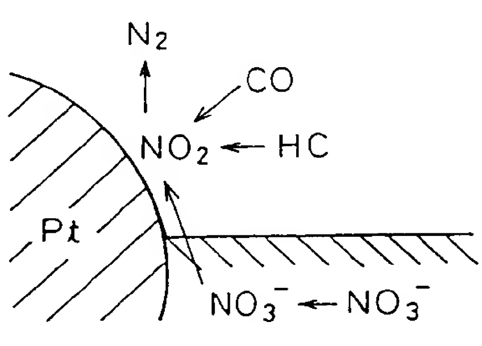


Fig.6(A)

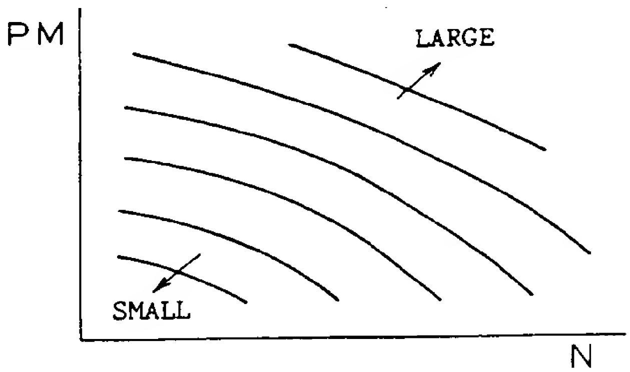


Fig.6(B)

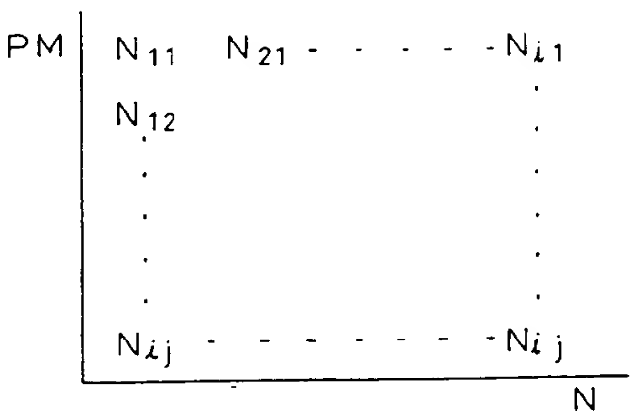


Fig.7

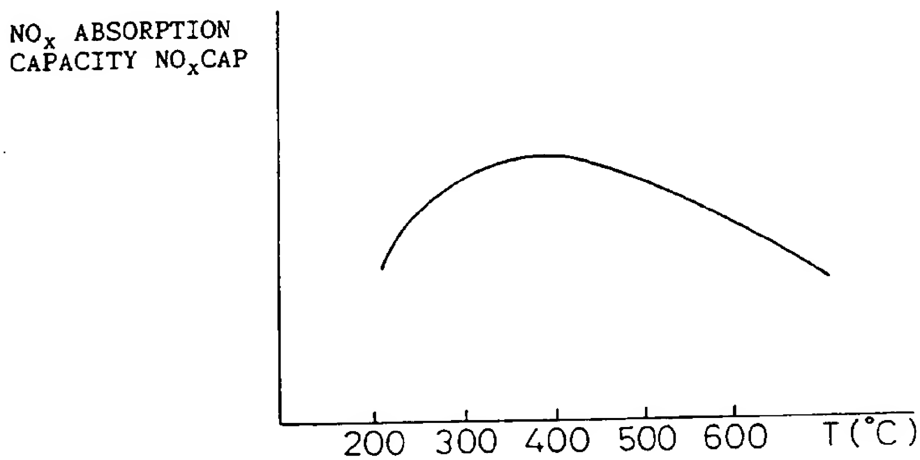


Fig.8

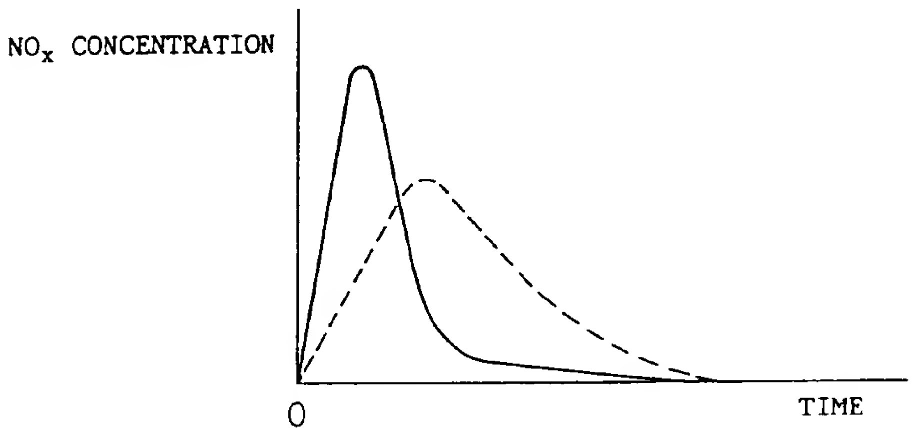


Fig.9

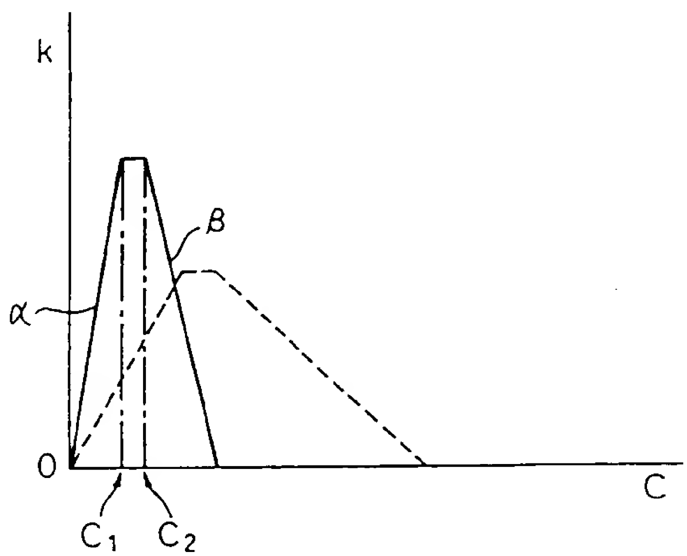


Fig.10

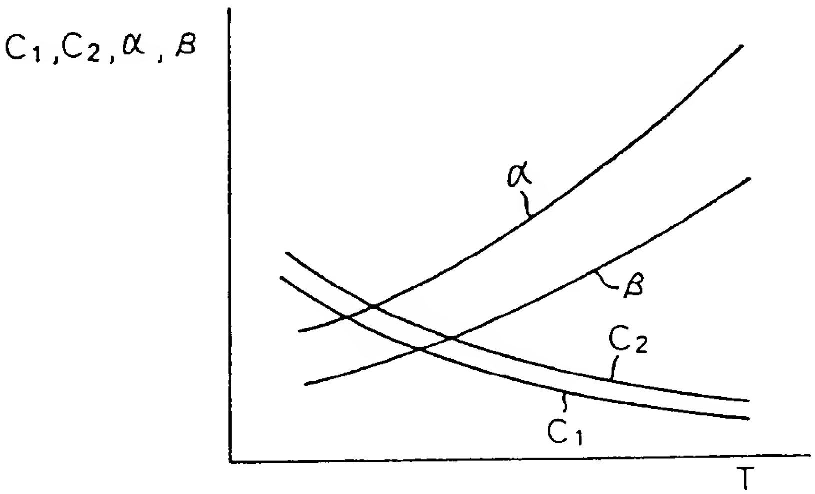


Fig.11

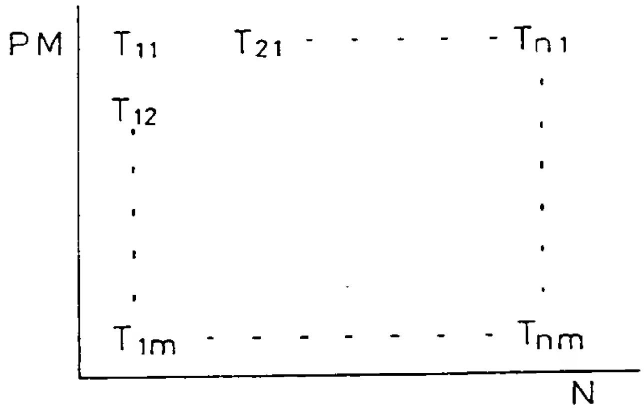


Fig.12

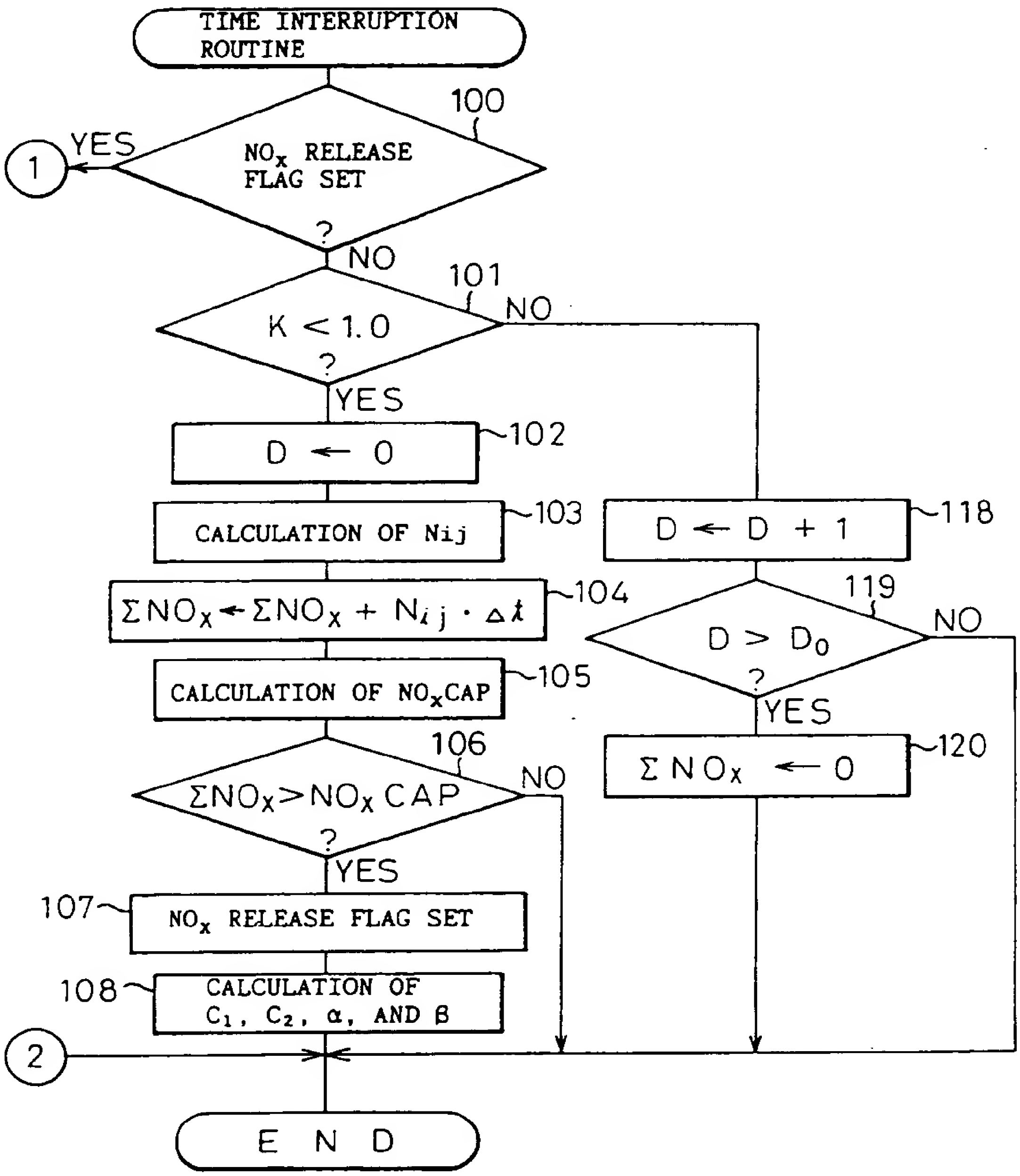

TIME INTERRUPTION ROUTINE
100
NOx RELEASE FLAG SET ?
YES
1
NO
101
K < 1.0 ?
NO
YES
D ← 0
102
CALCULATION OF Nij
103
ΣNOx ← ΣNOx + Nij · Δt
104
CALCULATION OF NOxCAP
105
106
ΣNOx > NOx CAP ?
NO
YES
107
NOx RELEASE FLAG SET
108
CALCULATION OF C1, C2, α, AND β
2
D ← D + 1
118
119
D > D0 ?
NO
YES
ΣNOx ← 0
120
E N D

Fig.13

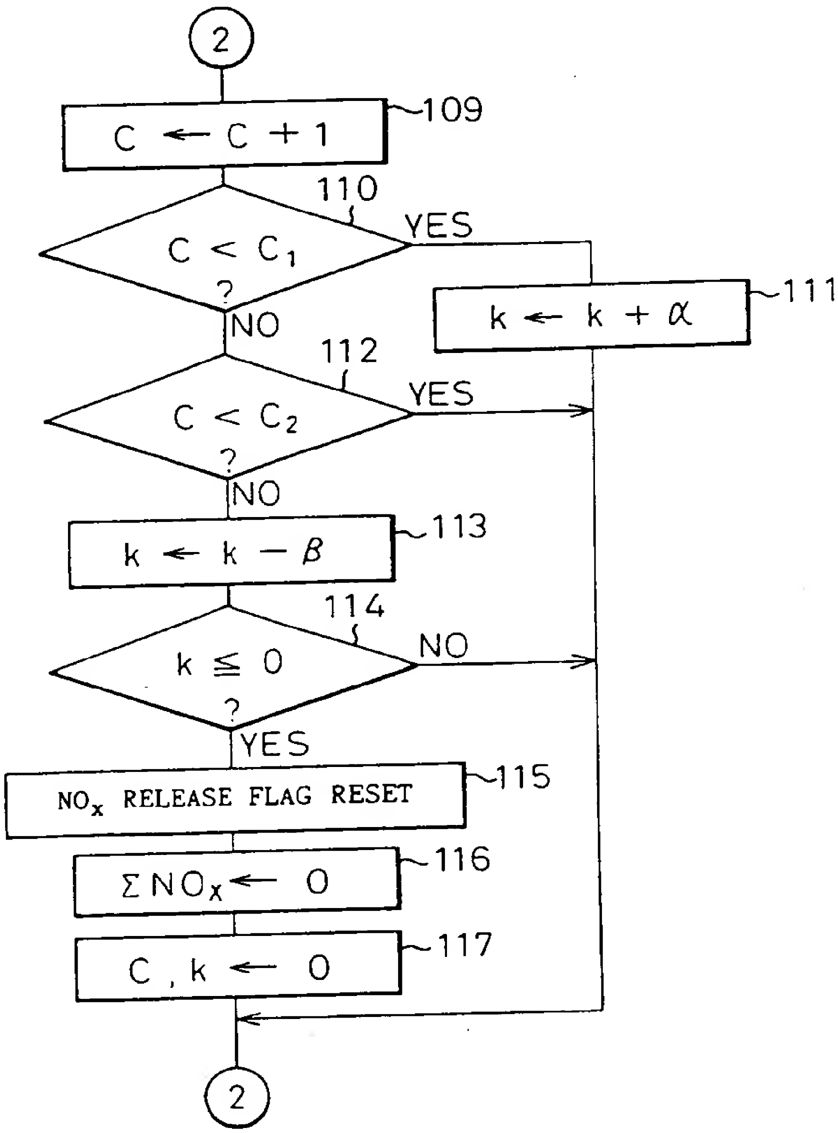

2
C ← C + 1
109
110
C < C1 ?
YES
NO
k ← k + α
111
112
C < C2 ?
YES
NO
k ← k − β
113
114
k ≦ 0 ?
NO
YES
NOx RELEASE FLAG RESET
115
Σ NOx ← 0
116
C , k ← 0
117
2

Fig.14

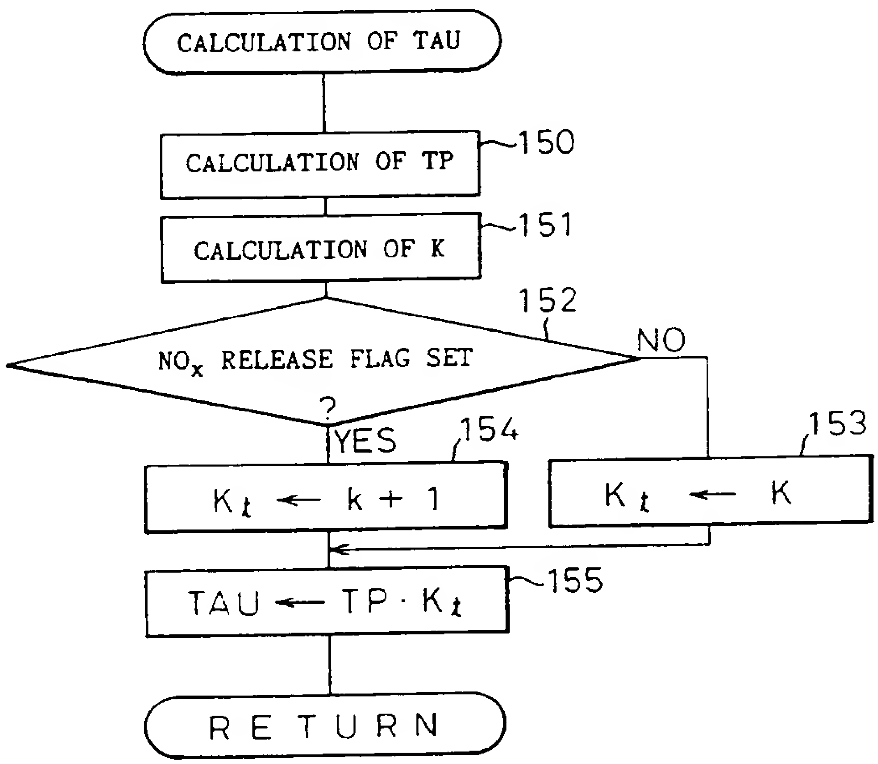

CALCULATION OF TAU
CALCULATION OF TP
150
CALCULATION OF K
151
152
NO_x RELEASE FLAG SET ?
NO
YES
154
153
$K_t \leftarrow k + 1$
$K_t \leftarrow K$
155
$TAU \leftarrow TP \cdot K_t$
RETURN

Fig.15

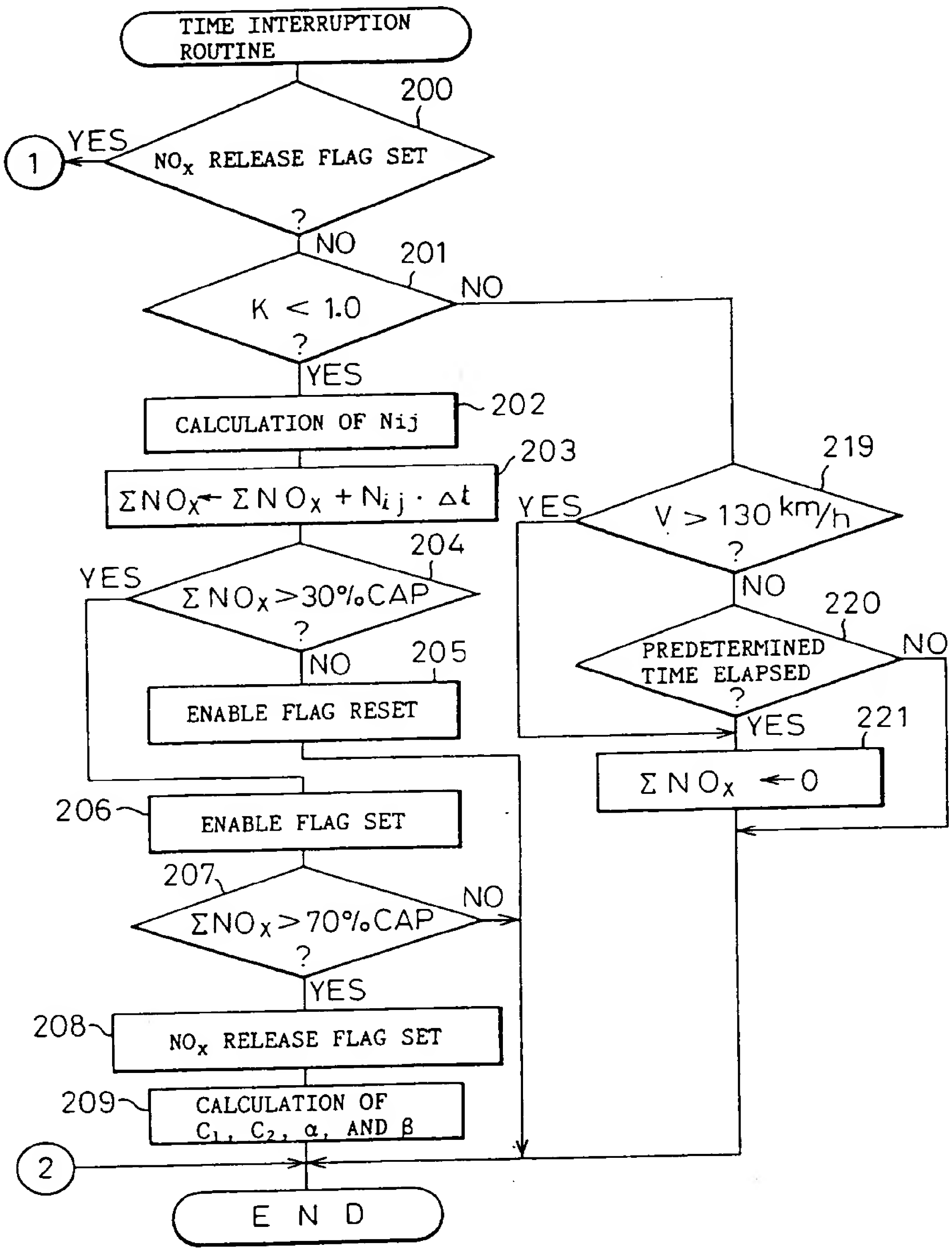

TIME INTERRUPTION ROUTINE
200
NOx RELEASE FLAG SET ?
YES
1
NO
201
K < 1.0 ?
NO
YES
CALCULATION OF Nij
202
203
ΣNOx ← ΣNOx + Nij · Δt
204
ΣNOx > 30%CAP ?
YES
NO
205
ENABLE FLAG RESET
206
ENABLE FLAG SET
207
ΣNOx > 70%CAP ?
NO
YES
208
NOx RELEASE FLAG SET
209
CALCULATION OF C1, C2, α, AND β
2
END
219
V > 130 km/h ?
YES
NO
220
PREDETERMINED TIME ELAPSED ?
NO
YES
221
ΣNOx ← 0

Fig.16

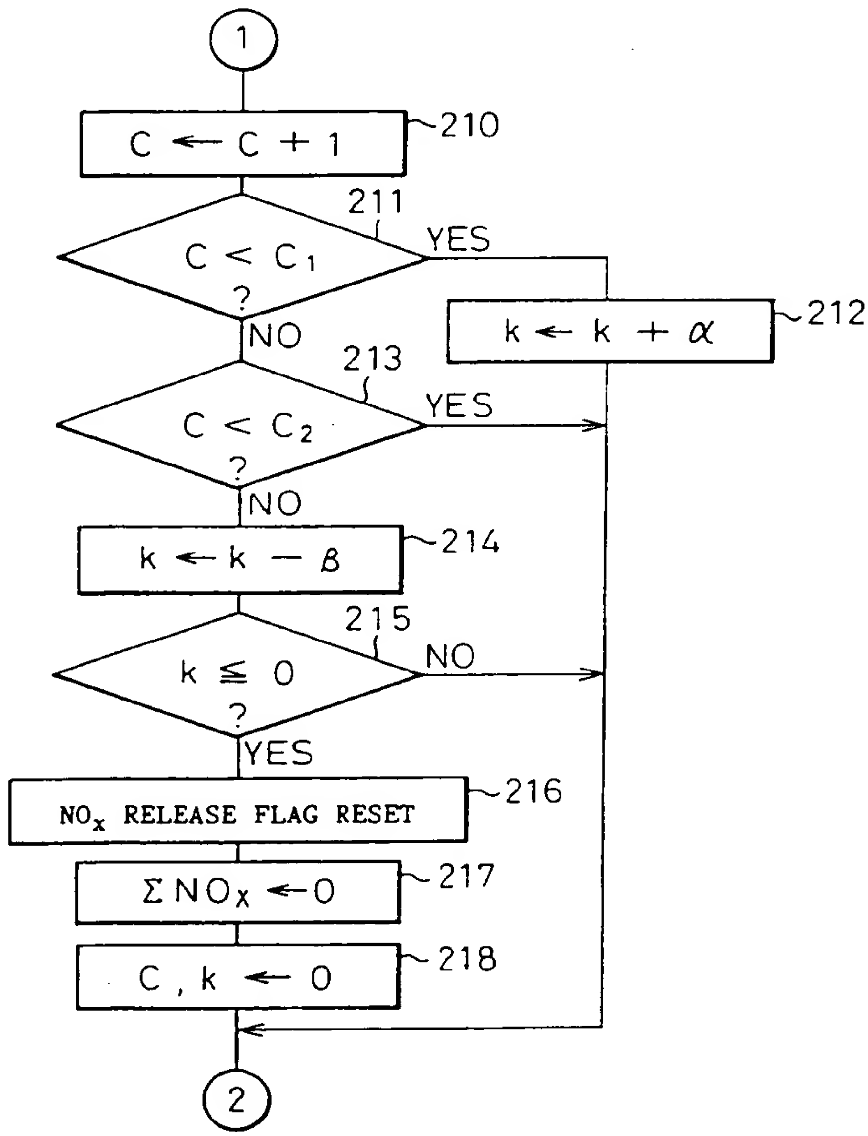

1
C ← C + 1
210
211
C < C1 ?
YES
NO
k ← k + α
212
213
C < C2 ?
YES
NO
k ← k − β
214
215
k ≦ 0 ?
NO
YES
NOx RELEASE FLAG RESET
216
ΣNOx ← 0
217
C , k ← 0
218
2

Fig.17

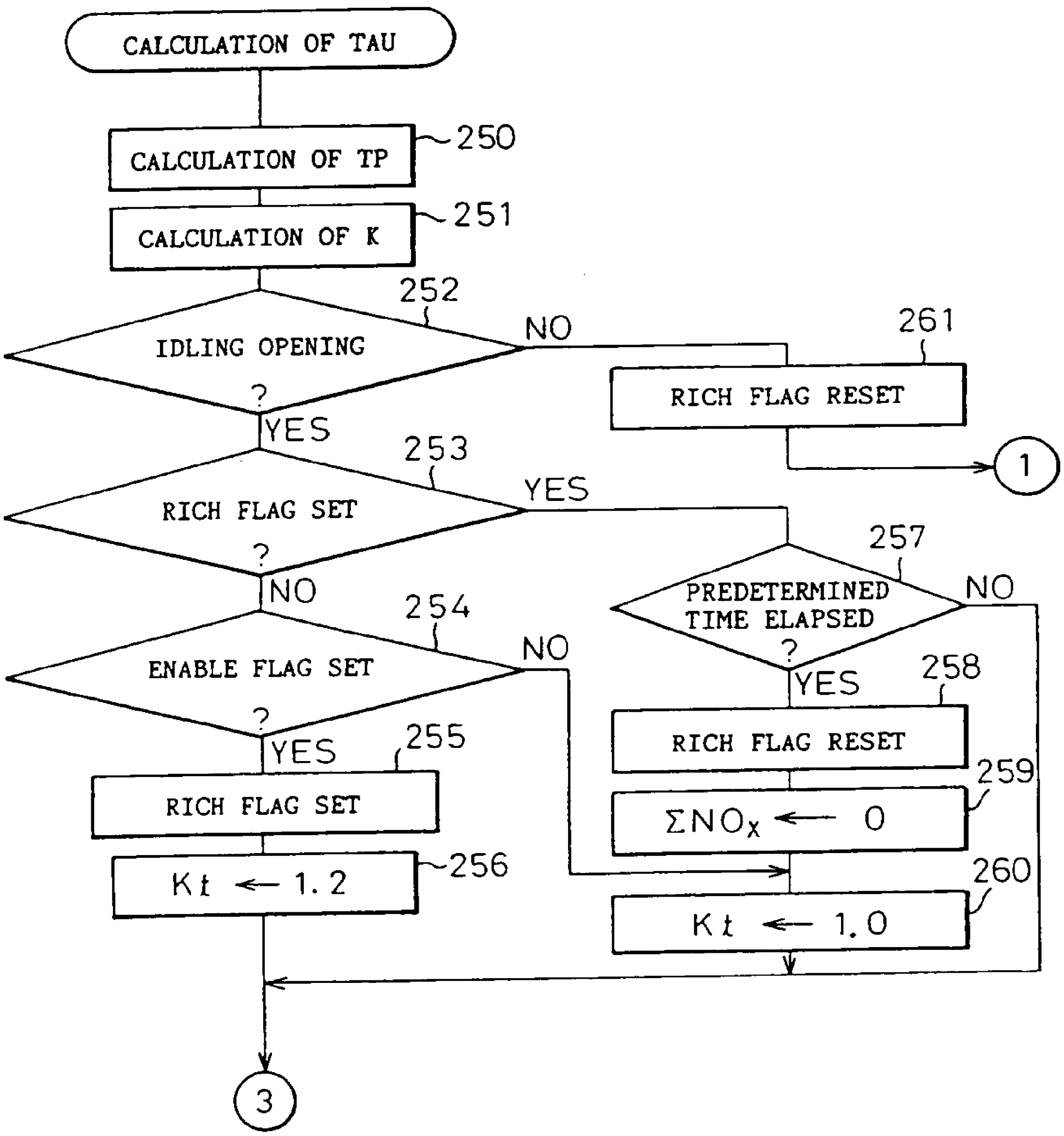

CALCULATION OF TAU
CALCULATION OF TP
250
CALCULATION OF K
251
IDLING OPENING ?
252
NO
YES
RICH FLAG RESET
261
1
RICH FLAG SET ?
253
YES
NO
PREDETERMINED TIME ELAPSED ?
257
NO
YES
ENABLE FLAG SET ?
254
NO
YES
RICH FLAG RESET
258
RICH FLAG SET
255
$\Sigma NO_x \leftarrow 0$
259
$Kt \leftarrow 1.2$
256
$Kt \leftarrow 1.0$
260
3

Fig.18

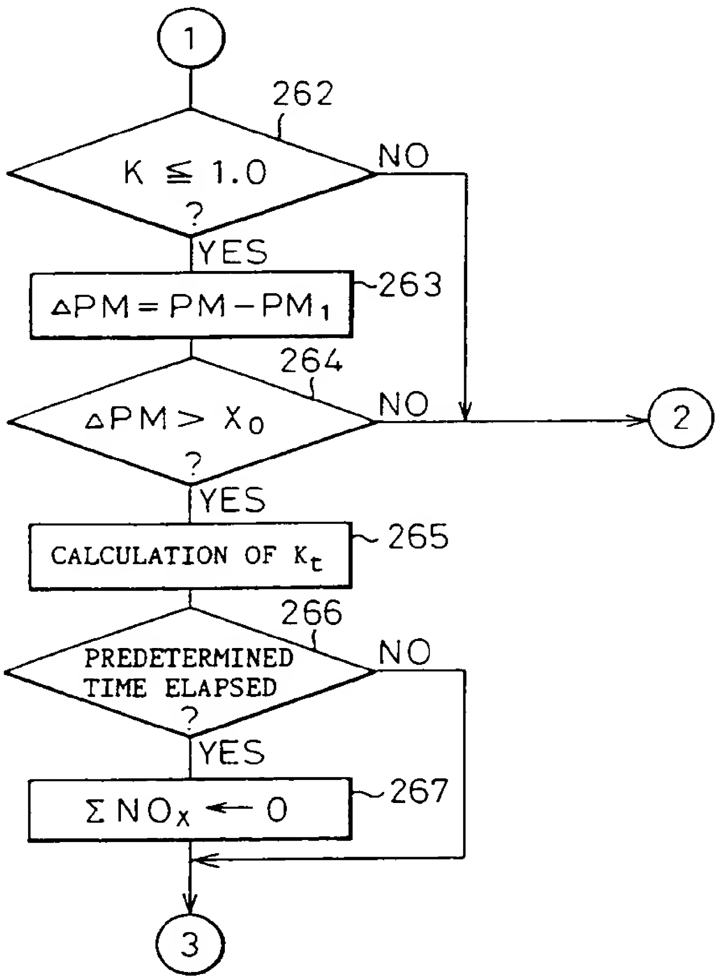

1
262
K ≦ 1.0 ?
NO
YES
ΔPM = PM − PM1
263
264
ΔPM > X0 ?
NO
2
YES
CALCULATION OF Kt
265
266
PREDETERMINED TIME ELAPSED ?
NO
YES
Σ NOx ← 0
267
3

Fig.19

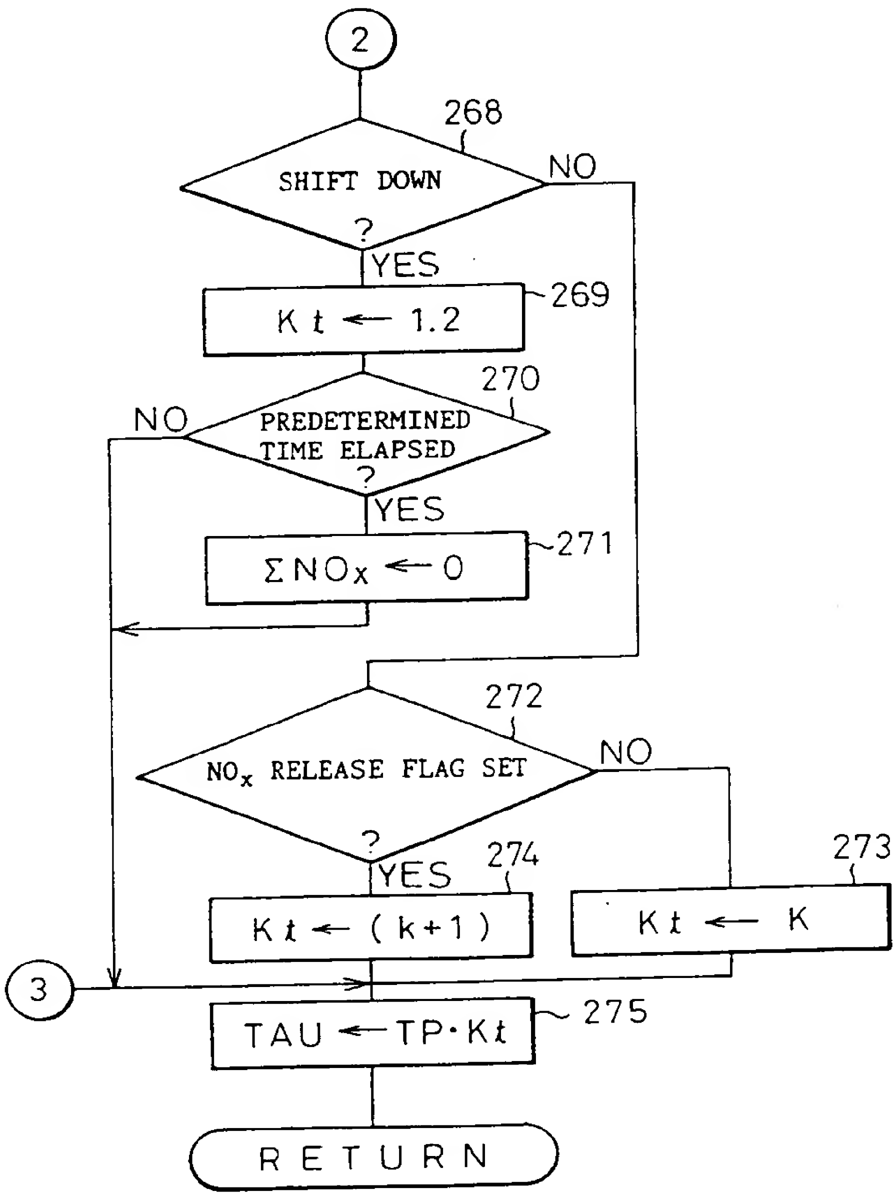

2
268
SHIFT DOWN ?
NO
YES
Kt ← 1.2
269
270
NO
PREDETERMINED TIME ELAPSED ?
YES
ΣNOx ← 0
271
272
NOx RELEASE FLAG SET ?
NO
YES
274
273
Kt ← (k+1)
Kt ← K
3
TAU ← TP·Kt
275
RETURN

Fig.20

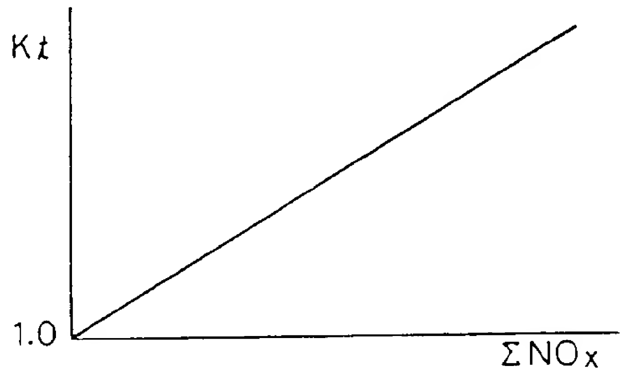


Fig.21

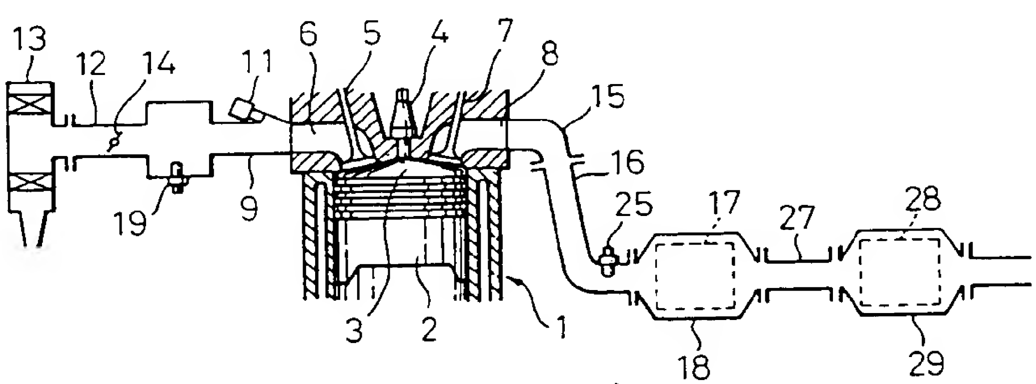
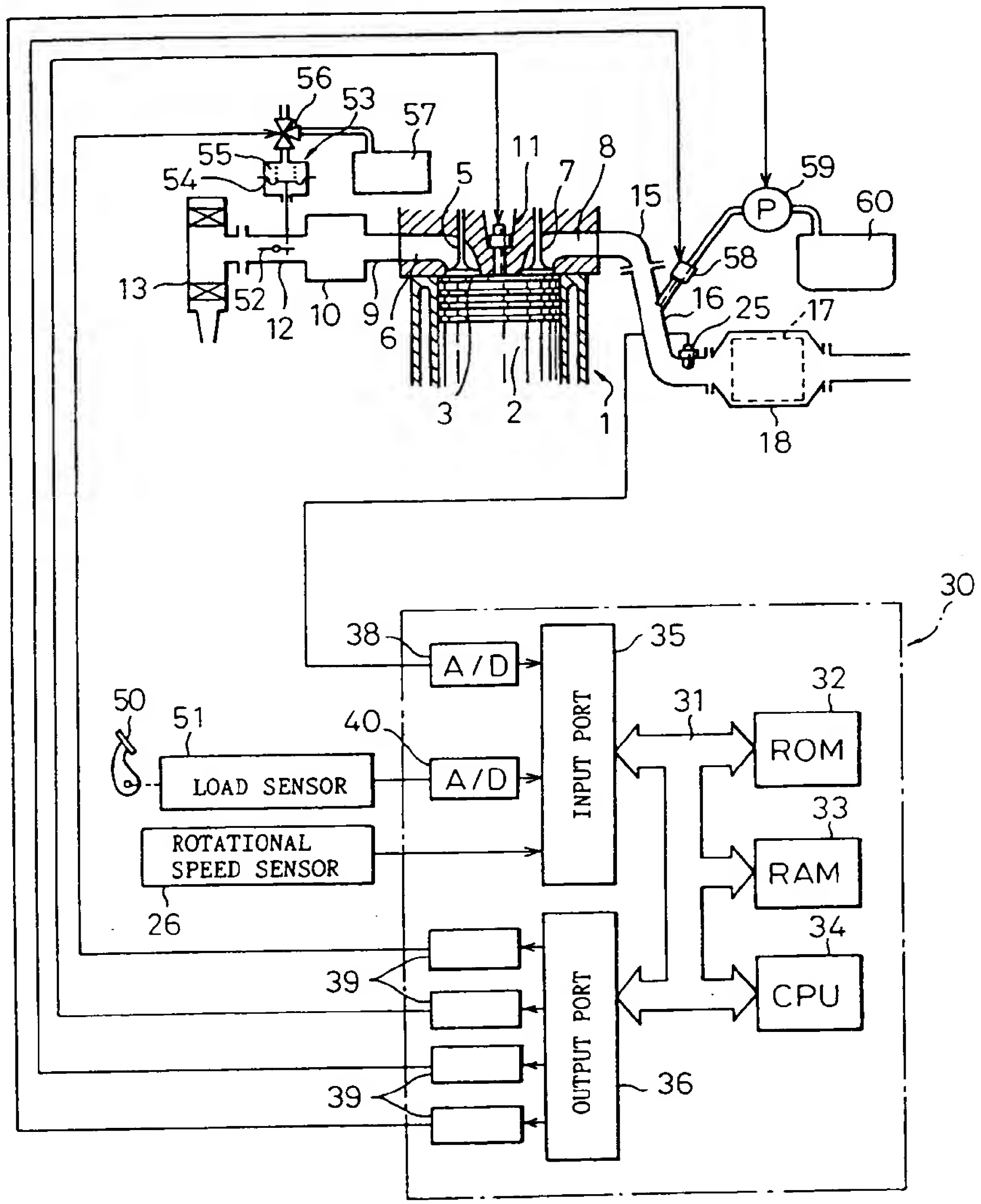


Fig.22



56
53
57
55
54
11
8
5
7
15
59
P
60
58
13
52
12
10
9
6
16
25
17
3
2
1
18
30
38
A/D
35
INPUT PORT
31
32
ROM
50
51
LOAD SENSOR
40
A/D
33
RAM
ROTATIONAL SPEED SENSOR
26
34
CPU
39
OUTPUT PORT
39
36

Fig.23(A)

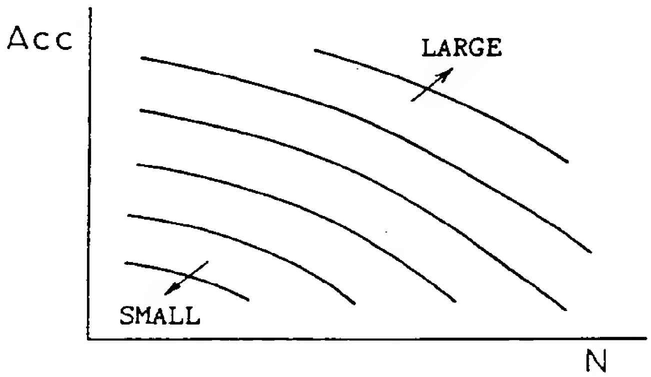


Fig.23(B)

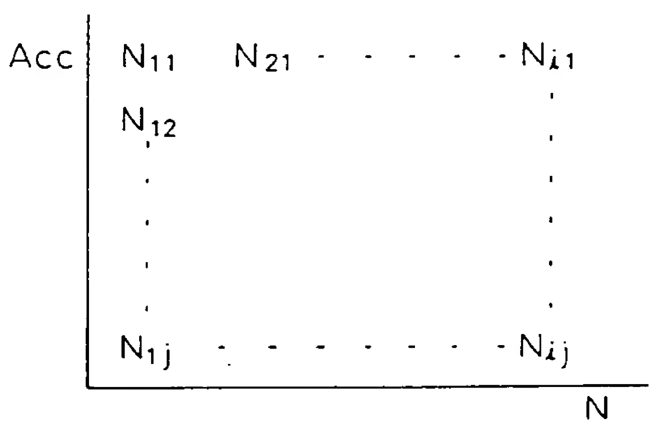


Fig.24

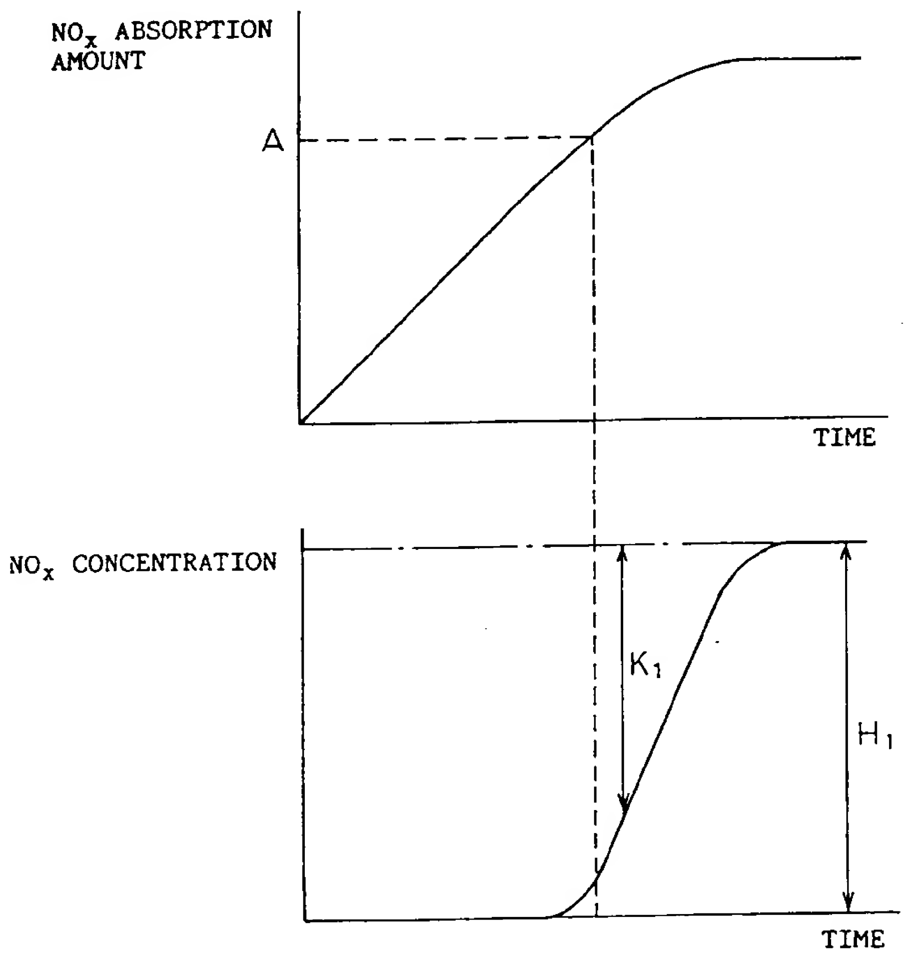


Fig.25

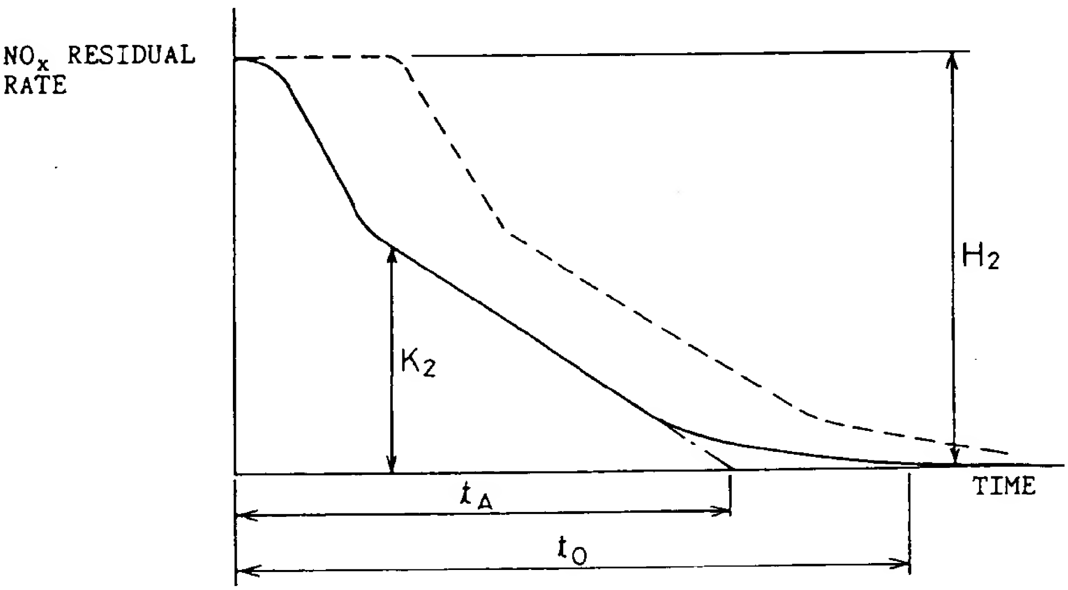


Fig.26

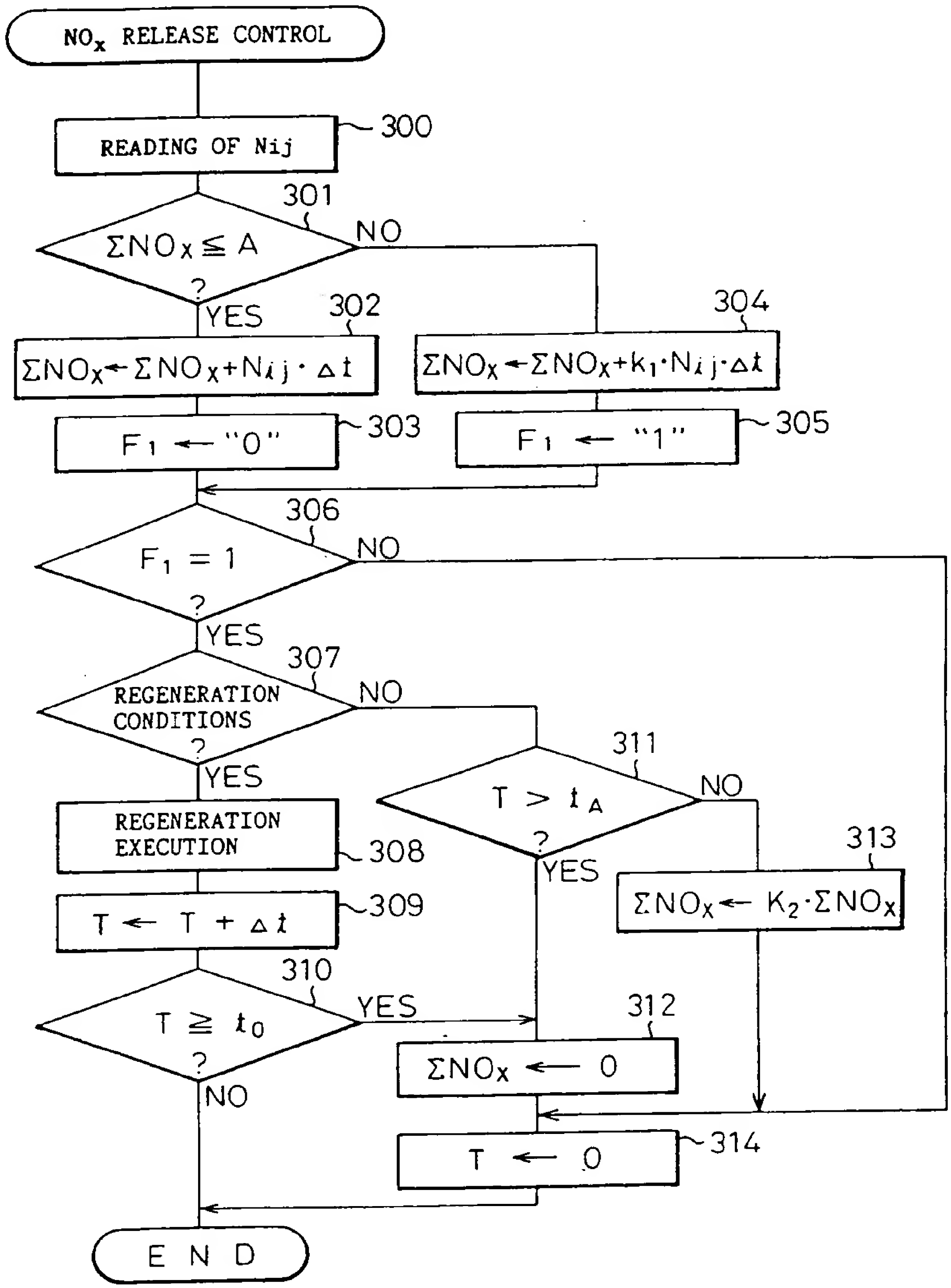
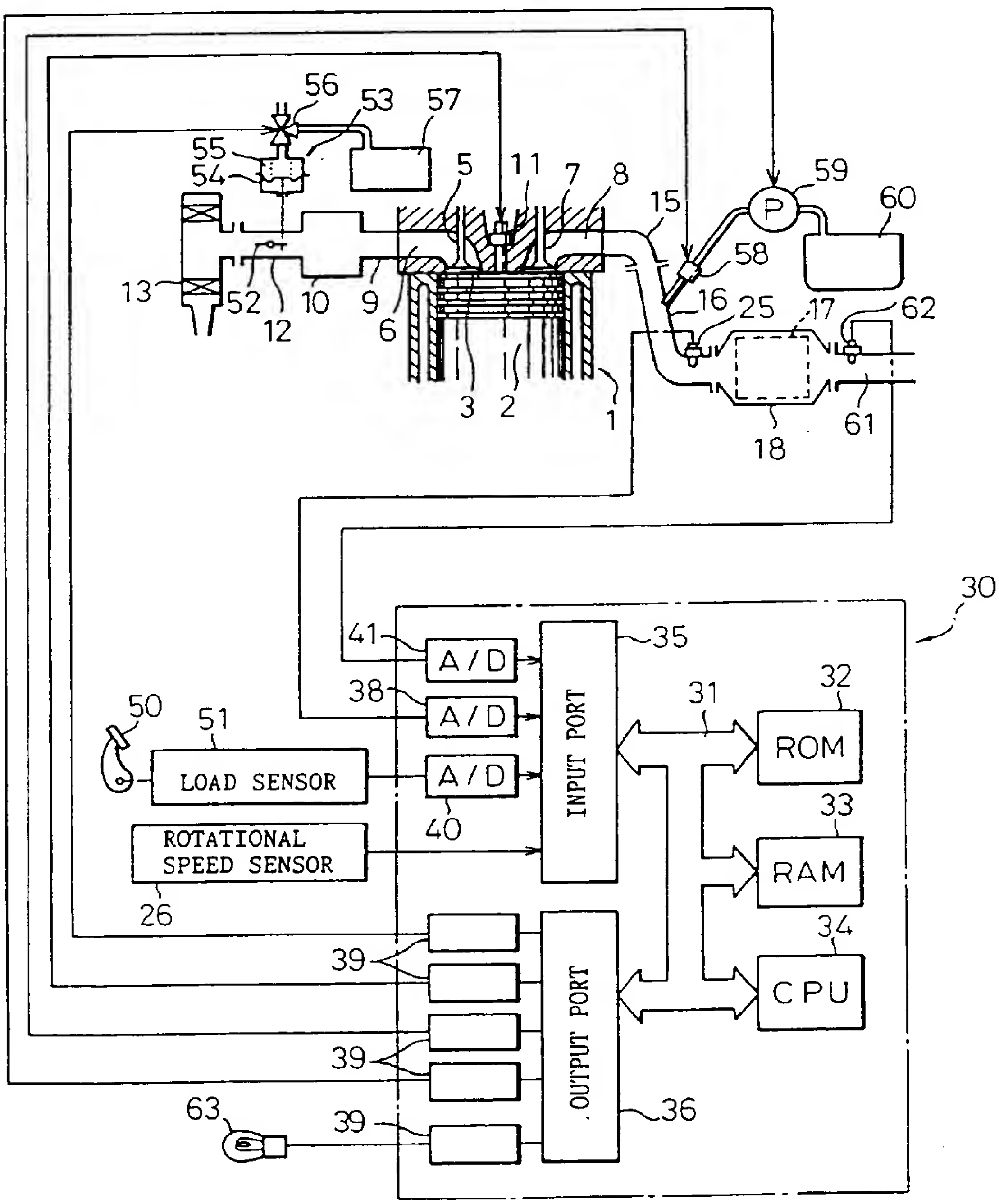

NOx RELEASE CONTROL
READING OF Nij
300
301
ΣNOx ≦ A ?
NO
YES
302
ΣNOx ← ΣNOx + Nij · Δt
304
ΣNOx ← ΣNOx + k1 · Nij · Δt
F1 ← "0"
303
F1 ← "1"
305
306
F1 = 1 ?
NO
YES
307
REGENERATION CONDITIONS ?
NO
YES
311
T > tA ?
NO
YES
REGENERATION EXECUTION
308
313
ΣNOx ← K2 · ΣNOx
T ← T + Δt
309
310
T ≧ t0 ?
YES
NO
312
ΣNOx ← 0
T ← 0
314
E N D

Fig.27



56
53
57
55
54
5
11
7
8
15
59
P
60
58
13
52
12
10
9
6
16
25
17
62
3
2
1
18
61
30
41
A/D
35
38
A/D
INPUT PORT
31
ROM
32
50
51
LOAD SENSOR
A/D
40
33
RAM
ROTATIONAL SPEED SENSOR
26
39
34
CPU
OUTPUT PORT
39
63
39
36

Fig. 28

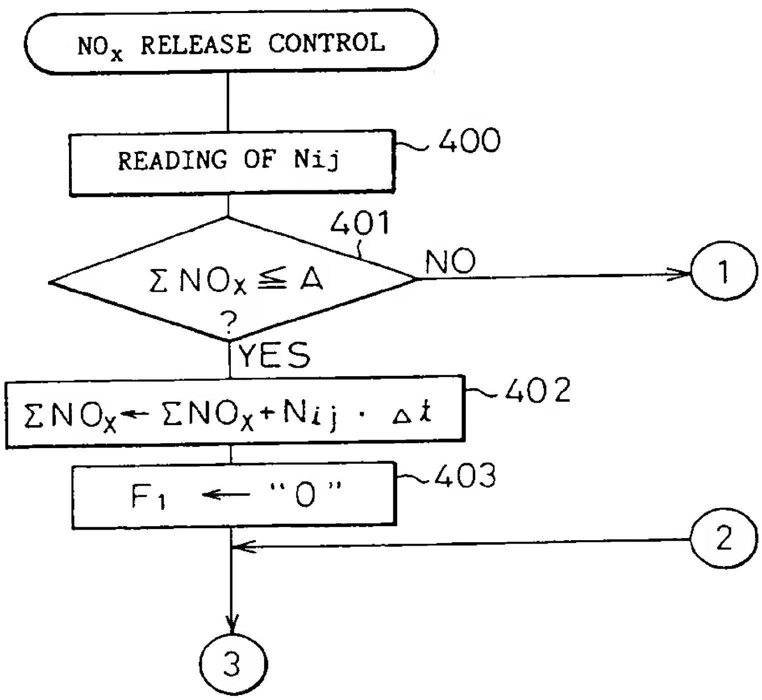

NOx RELEASE CONTROL
READING OF Nij
400
401
ΣNOx ≦ A ?
NO
1
YES
ΣNOx ← ΣNOx + Nij · Δt
402
F1 ← "0"
403
2
3

Fig. 29

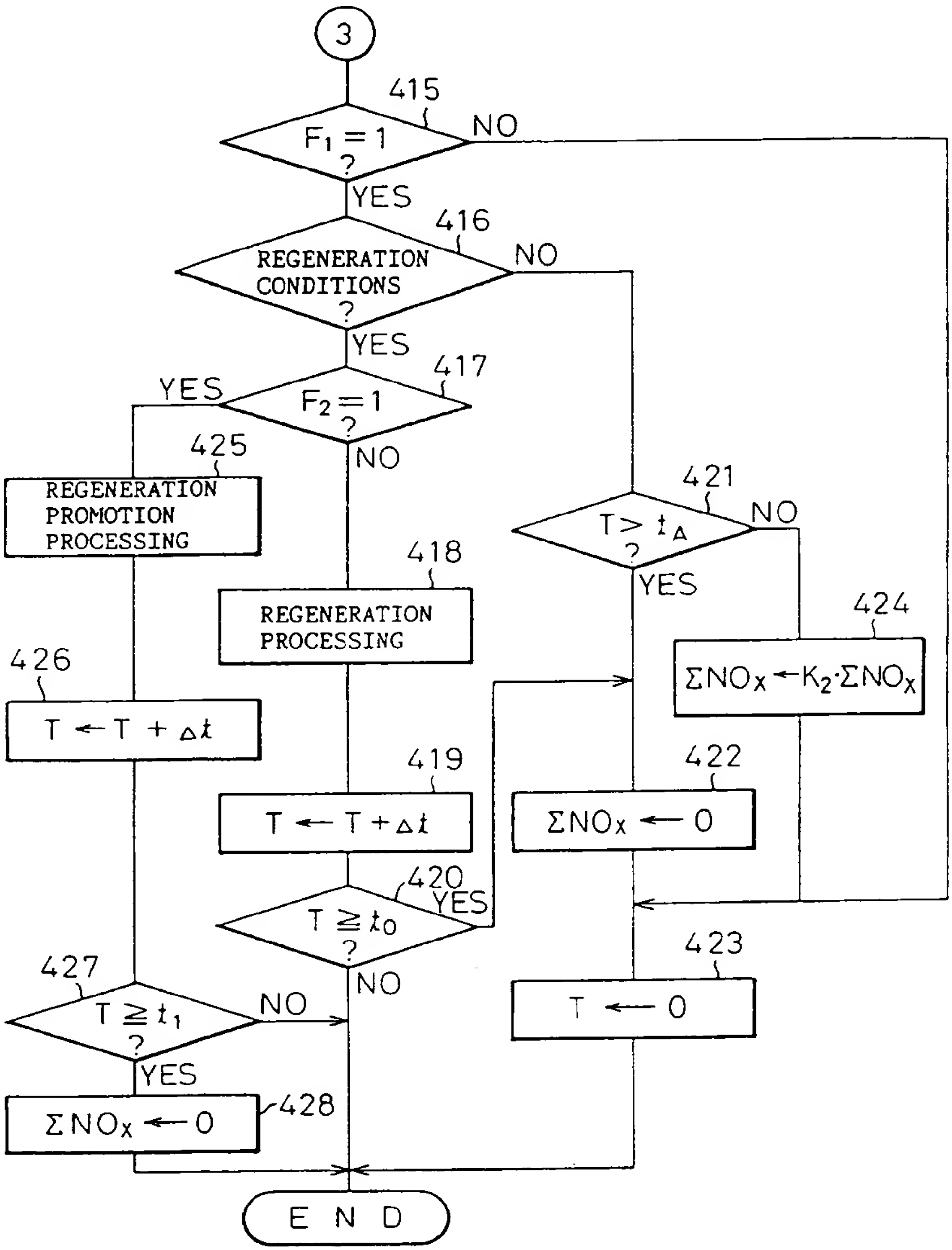
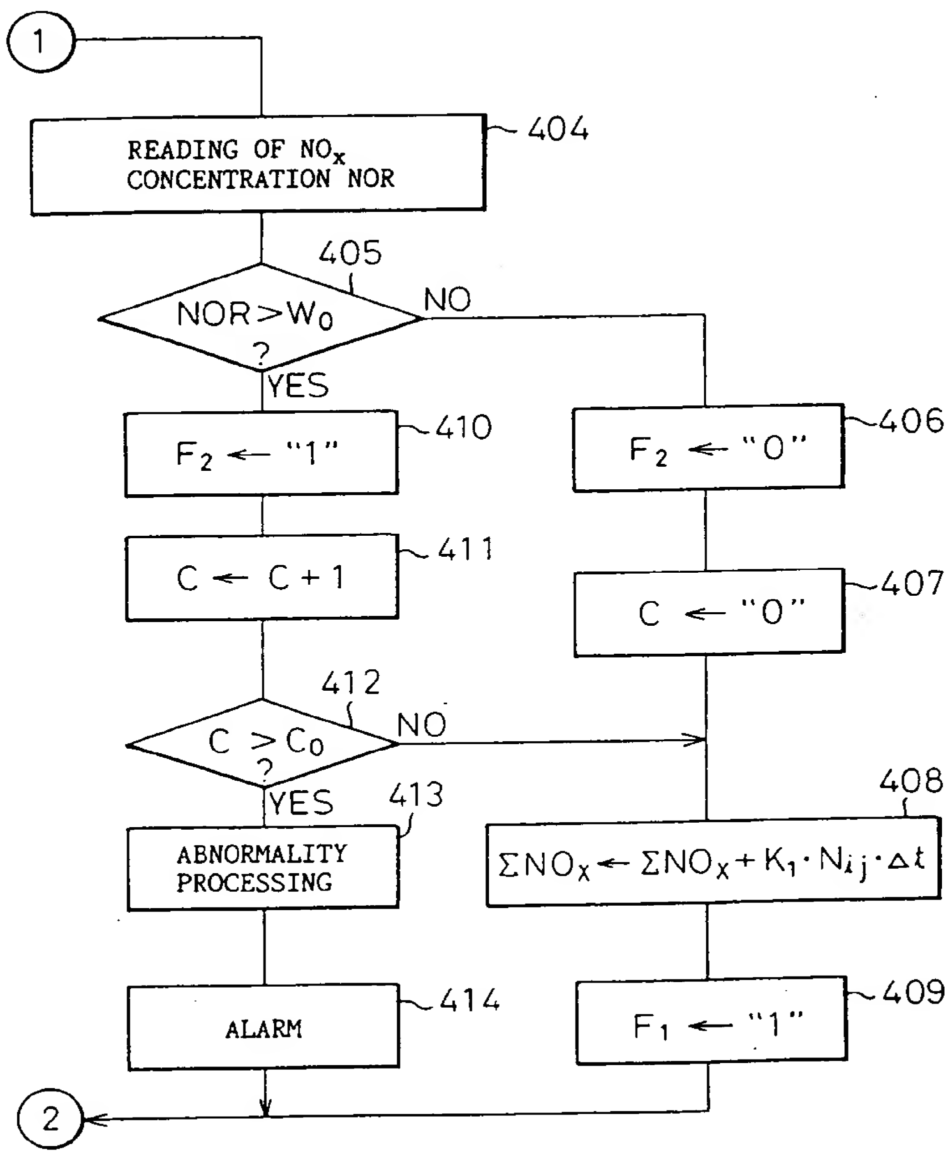

3
415
$F_1 = 1$?
NO
YES
416
REGENERATION CONDITIONS ?
NO
YES
417
$F_2 = 1$?
YES
NO
425
REGENERATION PROMOTION PROCESSING
421
$T > t_A$?
NO
YES
418
REGENERATION PROCESSING
424
$\Sigma NO_X \leftarrow K_2 \cdot \Sigma NO_X$
426
$T \leftarrow T + \Delta t$
419
$T \leftarrow T + \Delta t$
422
$\Sigma NO_X \leftarrow 0$
420
$T \geqq t_0$?
YES
NO
423
427
$T \geqq t_1$?
NO
YES
$T \leftarrow 0$
$\Sigma NO_X \leftarrow 0$
428
END

Fig.30


1
READING OF NOx CONCENTRATION NOR
404
405
NOR>W0 ?
NO
YES
F2 ← "1"
410
F2 ← "0"
406
C ← C+1
411
C ← "0"
407
412
C > C0 ?
NO
YES
413
408
ABNORMALITY PROCESSING
ΣNOx ← ΣNOx + K1·Nij·Δt
ALARM
414
F1 ← "1"
409
2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP93/00778

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl^5 F01N3/28, F01N3/24, B01D53/34, B01J23/58, F02D41/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl^5 F01N3/28, F01N3/24, B01D53/34, B01J23/58, F02D41/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1926 - 1993
Kokai Jitsuyo Shinan Koho 1971 - 1993

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP, A, 2-149715 (Mazda Motor Corp.), June 8, 1990 (08. 06. 90), Lines 3 to 13, column 3 (Family: none)	1-37
A	JP, B2, 1-56816 (Ebara-Infilco Co., Ltd.), December 1, 1989 (01. 12. 89), Lines 3 to 26, column 3 (Family: none)	1-37
A	JP, A, 4-141219 (Mazda Motor Corp.), May 14, 1992 (14. 05. 92), Line 13, column 4 to line 3, column 5 (Family: none)	1-37
A	JP, A, 3-194113 (Mazda Motor Corp.), August 23, 1991 (23. 08. 91), Line 19, column 4 to line 19, column 5 (Family: none)	1-37
A	JP, U, 4-1617 (Toyota Motor Corp.), January 8, 1992 (08. 01. 92), Lines 8 to 19, column 3 (Family: none)	1-37

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
July 28, 1993 (28. 07. 93)	August 17, 1993 (17. 08. 93)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP93/00778

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, A, 3-124909 (Mitsubishi Motors Corp.), May 28, 1991 (28. 05. 91), Line 20, column 4 to line 20, column 5 (Family: none)	14, 15
Y	JP, A, 60-182325 (Toyota Motor Corp.), September 17, 1985 (17. 09. 85), Line 13, column 8 to line 7, column 9 & US, A, 4682577	30, 32
Y	JP, A, 53-115687 (Matsushita Electric Ind. Co., Ltd.), October 9, 1978 (09. 10. 78), Line 4, column 1 to line 2, column 2 & JP, B2, 57-27739	35
Y	JP, A, 64-30643 (Matsushita Electric Ind. Co., Ltd.), February 1, 1989 (01. 02. 89), Line 5, column 4 to line 10, column 5 (Family: none)	36